# 6.1 Hanford Groundwater Monitoring Project

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The strategy for managing and protecting groundwater resources at the Hanford Site focuses on protection of the Columbia River, human health, the environment, treatment of groundwater contamination, and limitation of contaminant migration from the 200 Areas (see Groundwater/Vadose Zone Integration Project reports DOE/RL-98-48, Draft C and DOE/RL-98-56). To implement this strategy, the Hanford Groundwater Monitoring Project continues to monitor the quality of groundwater. The project is designed to detect and characterize new contaminant plumes and to document the distribution and movement of existing groundwater contamination. Monitoring provides the historical baseline to evaluate current and future risk from exposure to groundwater contamination and to decide on remedial options. Hydrogeologic studies are an integral part of the project because the geology and hydrology of the Hanford Site control the movement of contaminants in groundwater.

The effort to protect groundwater quality at the Hanford Site is implemented through programs to minimize and eliminate waste discharged to the soil column and through remediation work on the site. The Hanford Federal Facility Agreement and Consent Order (also known as the Tri-Party Agreement; Ecology et al. 1998) provides a framework for remediation of the Hanford Site, including groundwater, over a 40-year period. A summary of accomplishments in waste minimization and site remediation is presented in Section 2.3, "Activities, Accomplishments, and Issues."

DOE prepared a *Plan and Schedule to Discontinue Disposal of Liquids Into the Soil Column at the Hanford Site* (DOE 1987), which includes an alternative for treatment and disposal of contaminated effluents discharged to the soil. Of the 33 major waste streams identified in DOE (1987), the Phase I (high-priority) streams have either been eliminated or are being treated and diverted to the 200 Areas Treated Effluent Disposal Facility. In 1999, the State-Approved Land Disposal Site was the only place on the Hanford Site where liquid effluent containing radionuclide contamination discharged to the soil column. The locations of active permitted facilities through which wastewater was discharged to the ground in 1999 are shown in Figures 1.0.2 and 6.1.1 and are discussed in detail in Section 2.3, "Activities, Accomplishments, and Issues." In 1999, ~15% of the total volume of wastewater at the Hanford Site was discharged to the State-Approved Land Disposal Site and ~85% was discharged to the 200 Areas Treated Effluent Disposal Facility. All other facilities (e.g., cribs, trenches) where wastewater was historically discharged to the soil column are out of service. The only operational injection wells are associated with pump-and-treat remediation systems. Treated wastewater is reinjected back into the unconfined aquifer at these wells.

Groundwater is used for drinking water and other purposes at 12 DOE facilities on the Hanford Site. Pacific Northwest National Laboratory monitors DOE drinking water supplies for radiological constituents at the point of use or at the source. Results of the radiological monitoring are summarized in Section 4.3, "Radiological Surveillance of Hanford Site Drinking Water." The locations of wells completed in the unconfined aquifer that provide water for drinking, fire suppression, and cooling are shown in Figure 6.1.2.

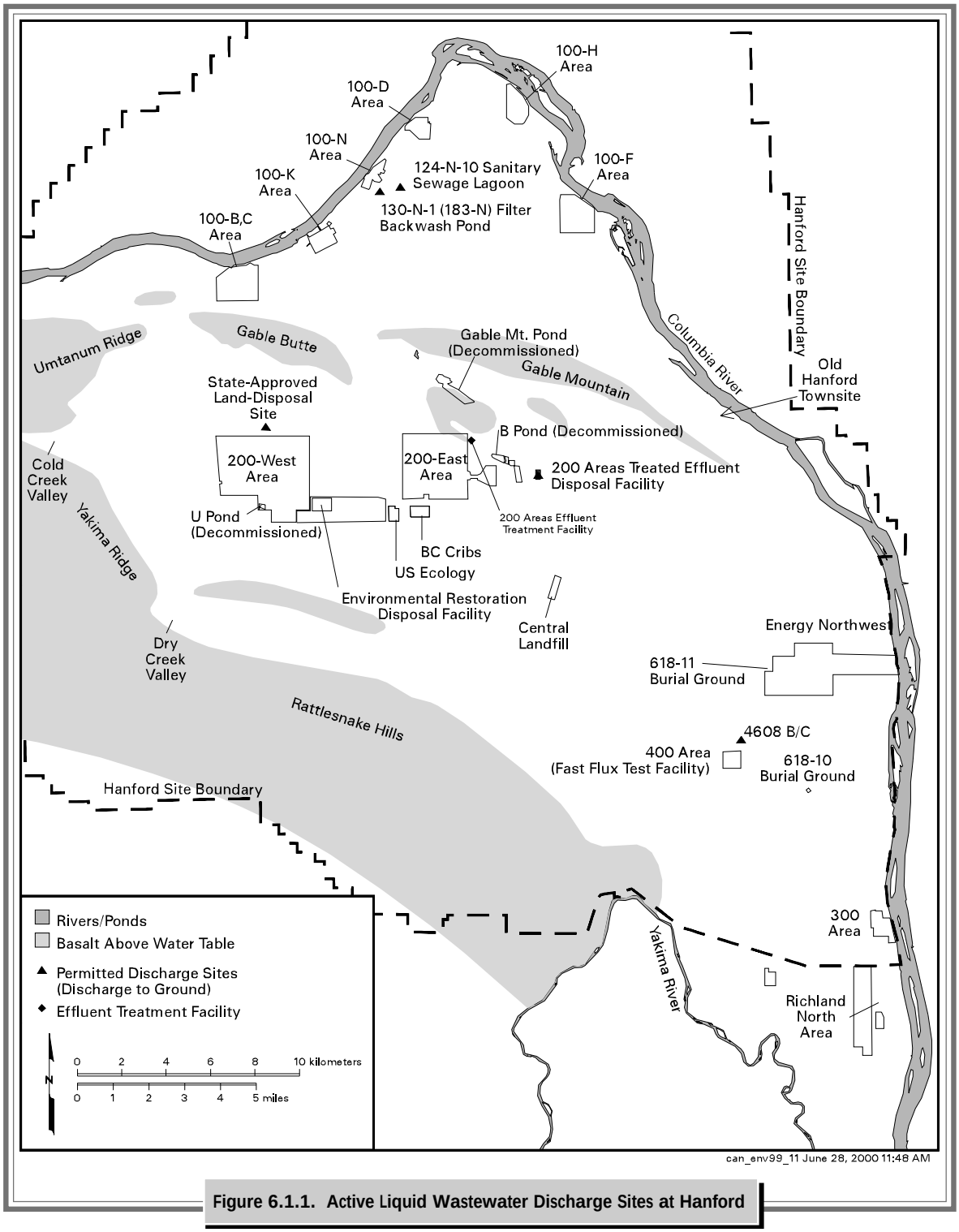


**Figure 6.1.1. Active Liquid Wastewater Discharge Sites at Hanford**

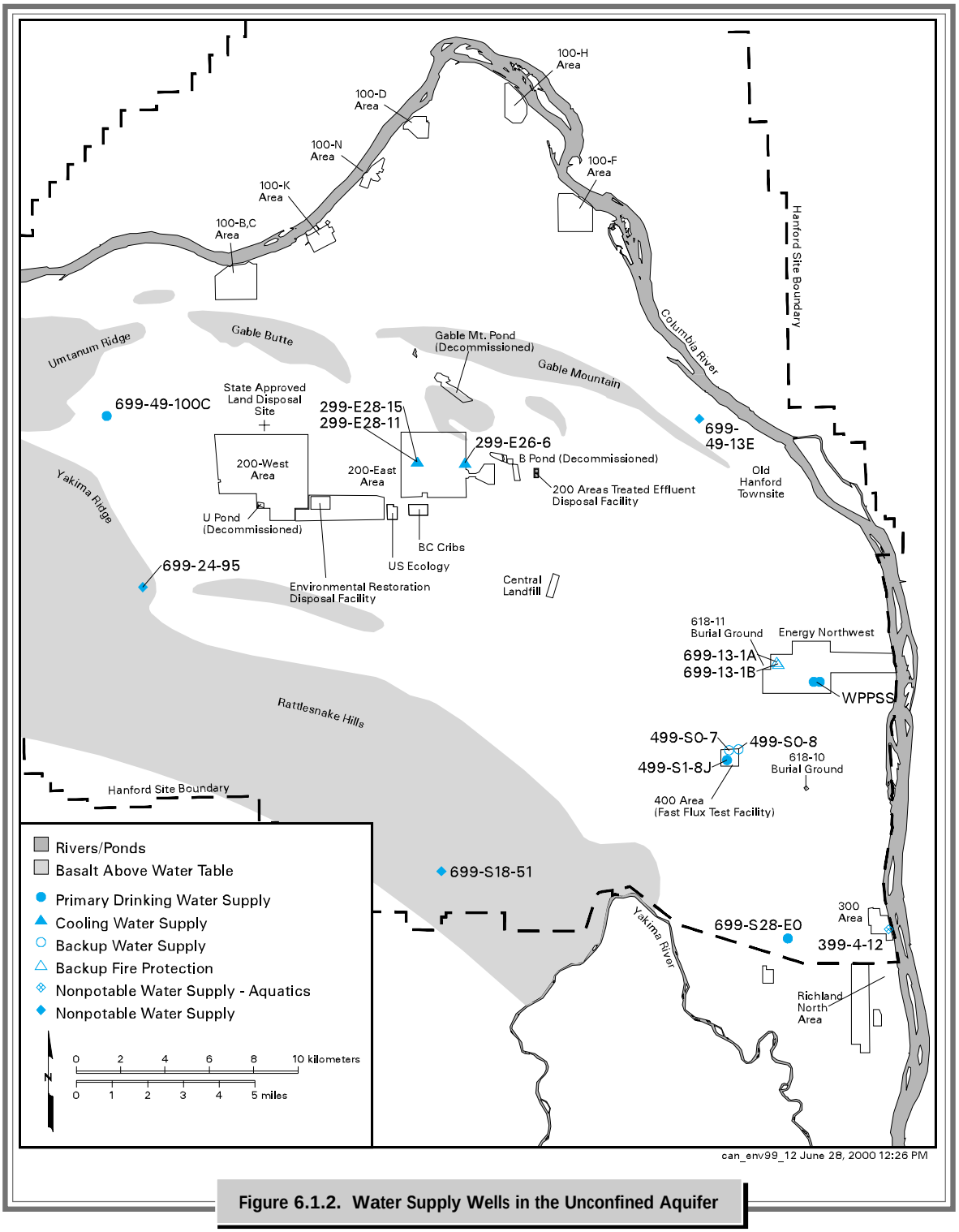


**Figure 6.1.2. Water Supply Wells in the Unconfined Aquifer**

# 6.1.1 Geologic Setting

The Hanford Site lies within the Pasco Basin, one of several structural basins within the Columbia Plateau. Principal geologic units beneath the Hanford Site include, in ascending order, the Columbia River Basalt Group, the Ringold Formation, and the Hanford formation (informal name) (Figure 6.1.3).

The Columbia River basalts were formed from lava that periodically erupted from volcanic fissures. The regional river system eroded the basalt and deposited sediment across the basalt surfaces between eruptions. Zones between the basalt flows and the sediment deposited as interbeds between basalt eruptions are frequently zones that are used as water sources in areas around the Hanford Site.

During the period when basalt was deposited, tectonic pressure was slowly deforming the basalt flows into the generally east-west ridges that border the Pasco Basin today. After the last major basalt eruption, sand and gravel of the Ringold Formation were deposited in the central portion of the Pasco Basin by the ancestral Columbia River as it meandered back and forth across the relatively flat basalt surface. Following uplift of the basalts and overlying sediment, the Columbia River began to erode, rather than deposit, sediment in the Pasco Basin. The uppermost mud layer was eroded from much of the Pasco Basin, and a caliche layer, part of the Plio-Pleistocene unit, developed in places on the eroded surface of the Ringold Formation. The caliche forms a low-permeability layer that affects migration of water through the vadose zone.

More recently, Hanford formation sediment was deposited by catastrophic ice age floods. Fine sand and silt were deposited in slackwater areas at the margins of the basin. However, primarily sand and

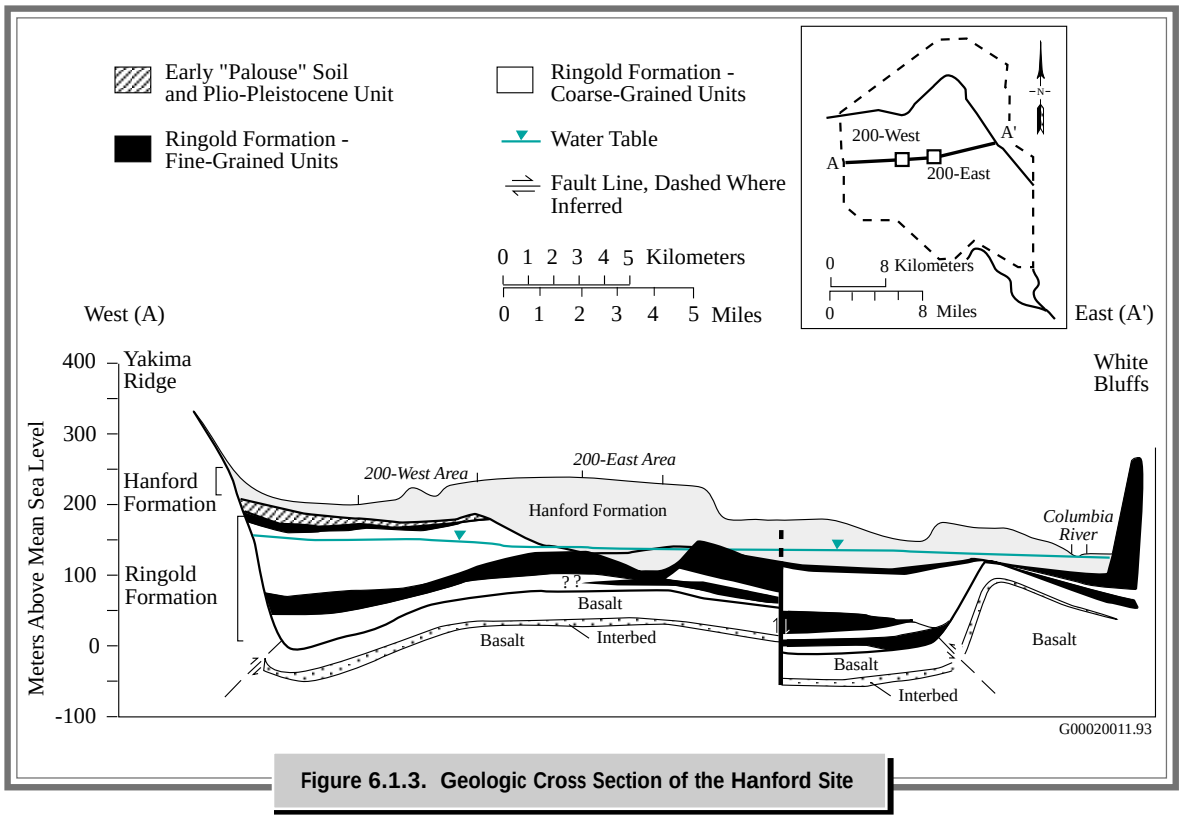


**Figure 6.1.3. Geologic Cross Section of the Hanford Site**

gravel were deposited on the Hanford Site. In places, the sediment is covered by up to a few meters of recent stream or windblown deposits.

More detailed information on the geology of the Pasco Basin can be found in BHI-00184, DOE/RW-0164 (Vol. 1), PNNL-13080, WHC-MR-0391, WHC-SD-EN-TI-014, and WHC-SD-EN-TI-019.

## 6.1.2 Groundwater Hydrology

Both confined and unconfined aquifers are present beneath the Hanford Site. An aquifer is a water-saturated geologic interval or unit that has a high permeability, meaning it can transmit significant quantities of water. A confined aquifer is bounded above and below by low-permeability materials that restrict the vertical movement of water. The confining layers may be dense rock, such as the central parts of basalt flows, silt, clay, or well-cemented sediment (i.e., caliche). Extensive, confined aquifers at the site are found primarily within interflows and interbeds of the Columbia River basalts. These are referred to as basalt-confined aquifers. Locally confined aquifers are also found below the clays and silts of the Ringold Formation.

An unconfined aquifer, or water-table aquifer, is overlain by unsaturated sediment. The upper surface of the saturated zone in an unconfined aquifer, which is called the water table, rises and falls in response to changes in the volume of water stored in the aquifer. In general, the unconfined aquifer at the Hanford Site is located in the Hanford and Ringold formations. In some areas, the water table is below the bottom of the Hanford formation and the unconfined aquifer is entirely within the Ringold Formation. Sand and gravel of the Hanford formation are unconsolidated and are generally much more permeable than the compacted and silty gravel of the Ringold Formation. Clay and silt units and zones of natural cementation form low-permeability zones within the Ringold Formation.

The unconfined aquifer forms the uppermost groundwater zone and has been directly effected by wastewater disposal at the Hanford Site. The unconfined aquifer discharges primarily into the Columbia River and is the most thoroughly monitored aquifer beneath the site. The Rattlesnake Ridge interbed is the uppermost, basalt-confined aquifer within the Pasco Basin and the Hanford Site. This aquifer and other confined aquifers are generally isolated from the unconfined aquifer by dense rock that forms the interior of the basalt flows. However, interflow between the unconfined aquifer and the basalt-confined aquifer system is known to occur at faults that bring a water bearing interbed in contact with other sediments or where the overlying basalt has been eroded to reveal an interbed (Newcomb et al. 1972, RHO-RE-ST-12 P, WHC-MR-0391). Additional information on the basalt-confined aquifer system can be found in PNL-10158 and PNL-10817.

The thickness of saturated sediment above the basalt bedrock is greater than 200 meters (656 feet) in some areas of the Hanford Site and thins out along the flanks of the uplifted basalt ridges (Figures 6.1.3 and 6.1.4). Depth from the ground surface to the water table ranges from less than 0.3 meter (1 foot) near the Columbia River to greater than 106 meters (348 feet) in the center of the site. The unconfined aquifer is bounded below by either the basalt surface or, in places, by relatively impervious clays and silts within the Ringold Formation. The water table defines the upper boundary of the unconfined aquifer. Laterally, the unconfined aquifer is bounded by basalt ridges and by the Yakima and Columbia Rivers. The basalt ridges have a low permeability and act as a barrier to the lateral flow of groundwater where they rise above the water table (RHO-BWI-ST-5, p. II-116).

The water-table elevation contours shown in Figure 6.1.5 indicate the direction of groundwater flow and the magnitude of the hydraulic gradient in

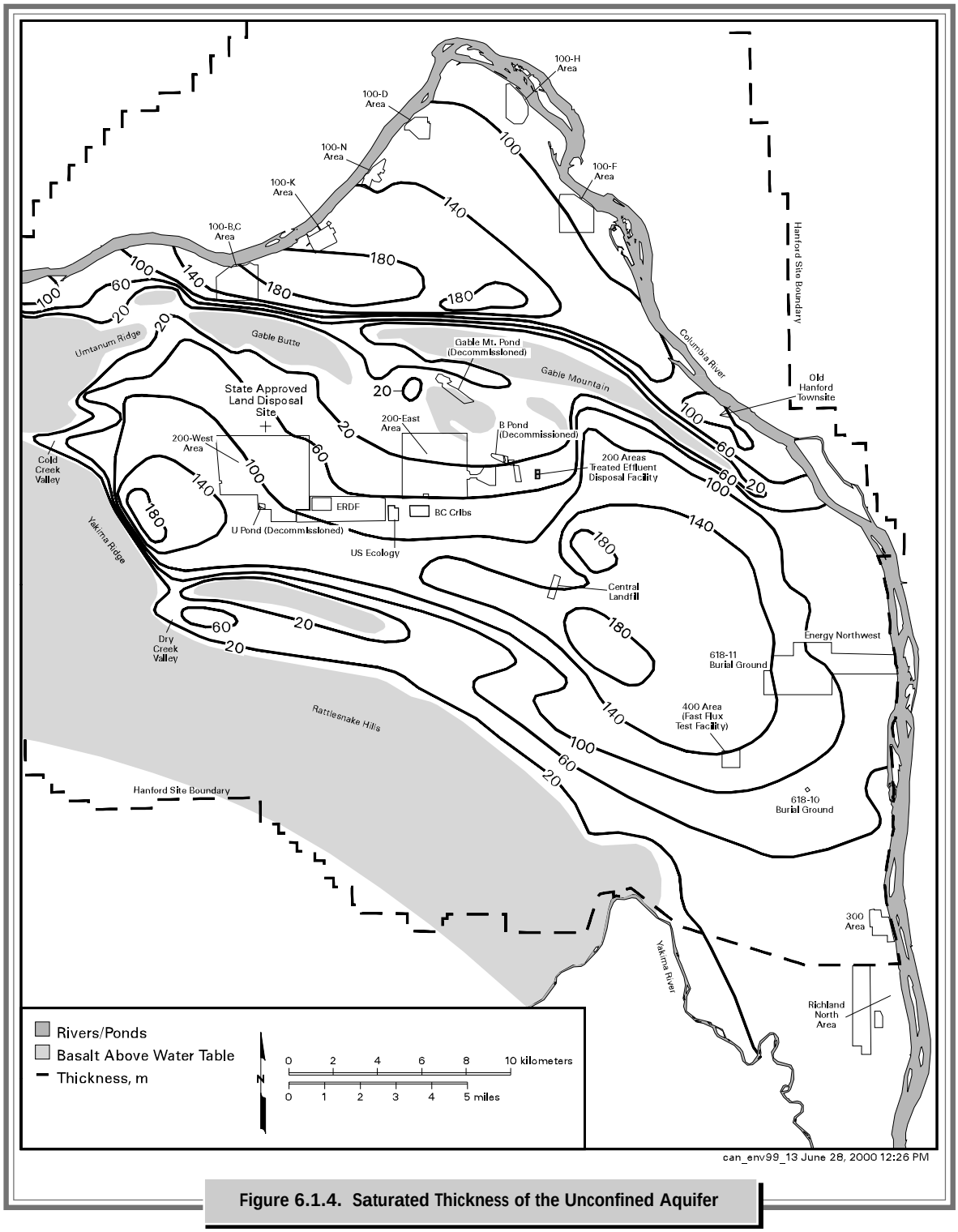


**Figure 6.1.4. Saturated Thickness of the Unconfined Aquifer**

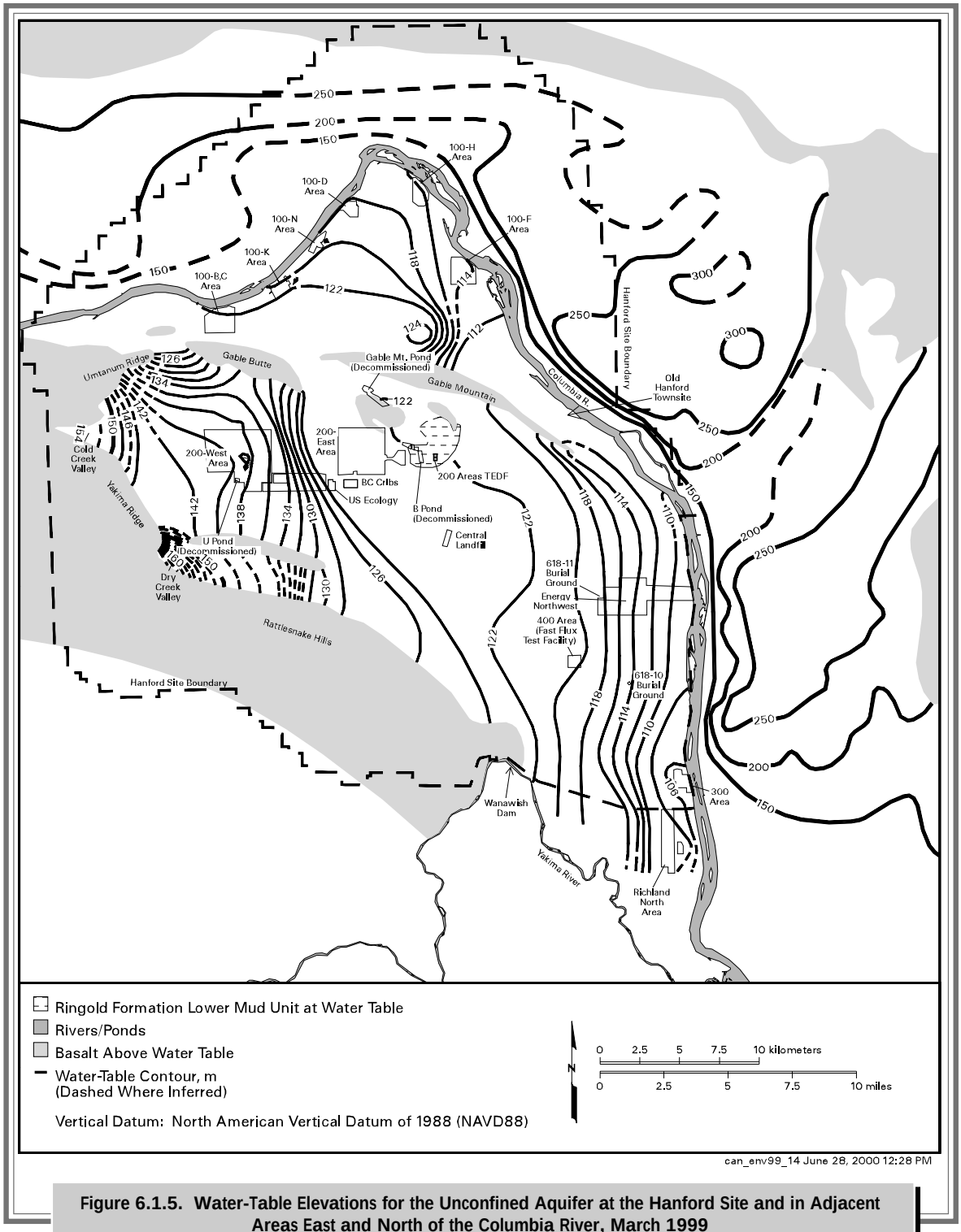


**Figure 6.1.5. Water-Table Elevations for the Unconfined Aquifer at the Hanford Site and in Adjacent Areas East and North of the Columbia River, March 1999**

the unconfined aquifer. Groundwater flow is generally perpendicular to the water-table contours from areas of higher elevation, or head, to areas of lower head. Areas where the contours are closer together are high-gradient areas, where the "driving force" for groundwater flow is greater. However, because sediment with low permeabilities inhibits groundwater flow, producing steeper gradients, a high gradient does not necessarily mean high groundwater velocity. Lower transmissivity and steeper gradients are often associated with areas where the water table is below the bottom of the Hanford formation and the aquifer is entirely within the less permeable Ringold sediment. Figure 6.1.6 shows the generalized distribution of transmissivity as determined from aquifer pumping tests and groundwater flow model calibration. Additional information on aquifer hydraulic properties at Hanford is presented in DOE/RW-0164 (Vol. 2) and PNL-8337.

Recharge of water within the unconfined aquifer (RHO-ST-42) comes from several sources. Natural recharge occurs from infiltration of precipitation along the mountain fronts, runoff from intermittent streams such as Cold and Dry Creeks on the western margin of the site, and limited infiltration of precipitation on the site. The Yakima River, where it flows along the southern boundary of the site, also recharges the unconfined aquifer. The Columbia River is the primary discharge area for the unconfined aquifer. However, the Columbia River also recharges the unconfined aquifer for short periods during high-river stage, when river water is transferred into the aquifer along the riverbank. Recharge from infiltration of precipitation is highly variable on the Hanford Site both spatially and temporally. The rate of natural recharge depends primarily on soil texture, vegetation, and climate (Gee et al. 1992, PNL-10285). Natural recharge rates range from near zero, where fine-grained soils and deep-rooted vegetation are present, to greater than 10 centimeters per year (4 inches per year) in areas where soils are coarse textured and bare of vegetation.

Large-scale, artificial recharge to the unconfined aquifer occurred as a result of past liquid waste disposal in the operating areas and offsite agricultural irrigation to the west and south. Discharge of wastewater caused the water table to rise over most of the Hanford Site. Since the peak discharge in 1984, discharge of wastewater to the ground has been significantly reduced and, in response, the water table subsequently declined over most of the site. The water table continues to decline, as illustrated by Figure 6.1.7. The water table declined up to 0.5 meter (1.6 feet) over most of the site between 1998 and 1999. A decline of 0.5 to 1.5 meters (1.6 to 4.9 feet) in the water table along the Columbia River from west of the 100-B,C Area to the Old Hanford Townsite was due to variations in river discharge during different times of the year. Beginning in 1999, annual water-level measurements were taken in March instead of June because the March water table is considered to represent the annual average water table (PNNL-13021). River discharge is typically lower in March than in June.

The decline in the water table has altered the flow pattern of the unconfined aquifer, which is generally from the recharge areas in the west to the discharge areas (primarily the Columbia River) in the east and north. Water levels in the unconfined aquifer have continually changed as a result of variations in the volume and location of wastewater discharge. Consequently, the movement of groundwater and its associated constituents has also changed with time.

Two major groundwater mounds formed in the vicinity of the 200-East and 200-West Areas in response to wastewater discharges. The first of these mounds was created by disposal at the 216-U-10 pond (U Pond) in the 200-West Area. After U Pond was decommissioned in 1984, the mound slowly dissipated. The water table continues to decline in this area (see Figure 6.1.7). The second major mound was created by discharge to the decommissioned, or former, 216-B-3 pond (B Pond), east of the 200-East Area. The water-table elevation near B Pond

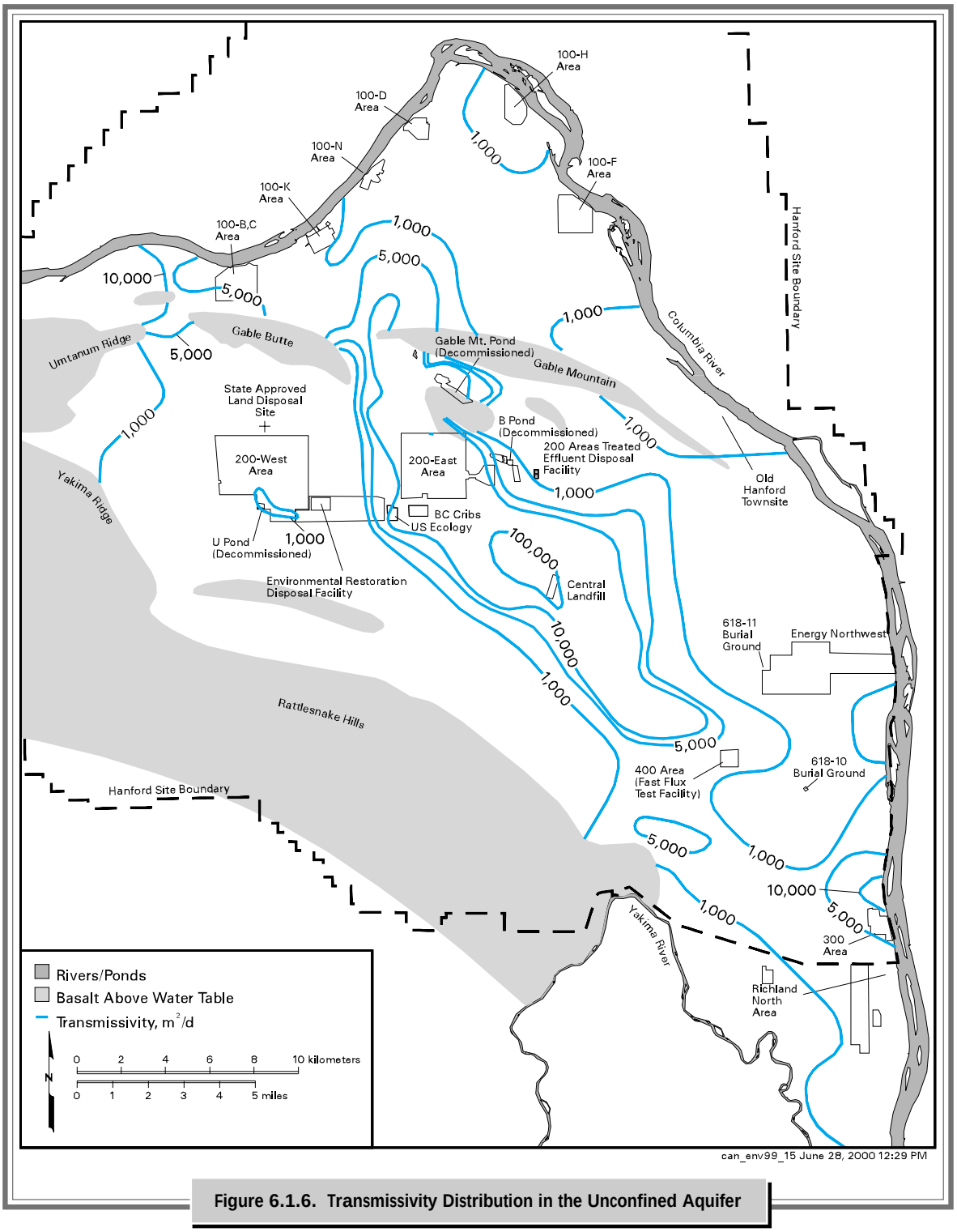


**Figure 6.1.6. Transmissivity Distribution in the Unconfined Aquifer**

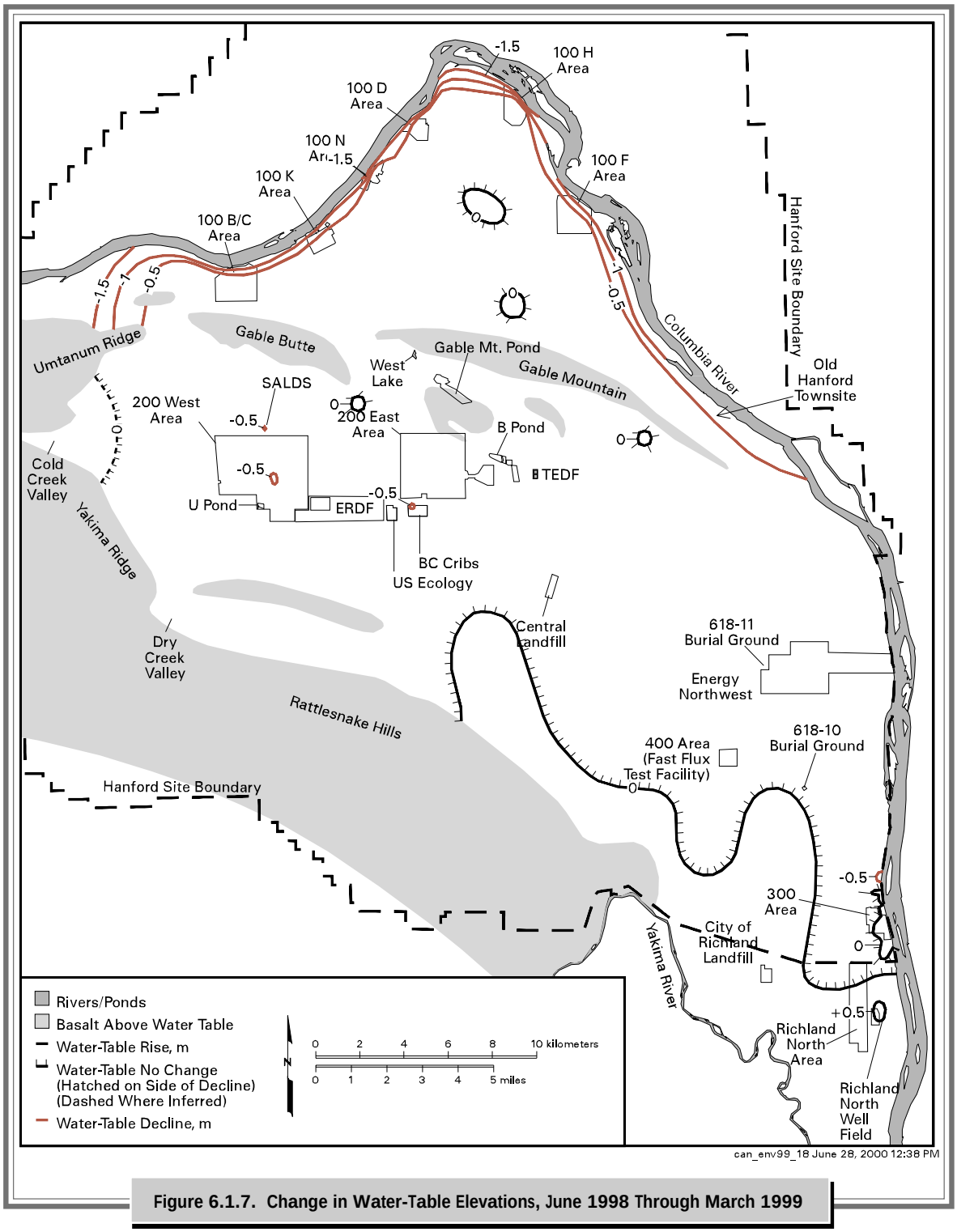


**Figure 6.1.7. Change in Water-Table Elevations, June 1998 Through March 1999**

increased to a maximum before 1990 and decreased because of reduced discharge. After discharge to B Pond ceased in August 1997, the decline in the water-table elevation accelerated. In 1999, the rate of decline in the water-table elevation slowed. Groundwater mounding related to wastewater discharges has also occurred in the 100 and 300 Areas. However, groundwater mounding in these areas is not as great as in the 200 Areas primarily because of lower discharge volumes.

## 6.1.3 Contaminant Transport

The history of contaminant releases and the physical and chemical principles of mass transport control the distribution of radionuclides and chemicals in groundwater. Processes that control the movement of these contaminants at the Hanford Site are discussed below.

Most of the groundwater contamination at the Hanford Site resulted from discharge of wastewater from reactor operations, reactor fuel fabrication, and processing of spent reactor fuel. Table 6.1.1 lists the principal contaminants found in each operational area and the type of operation that generated them. In the 100 Areas, discharges included reactor cooling water, fuel storage basin water, filter backwash, and smaller amounts of waste from a variety of other processes. In the 200 Areas, large quantities of wastewater from fuel reprocessing were discharged to the ground. Other contamination sources in the 200 Areas included plutonium purification waste and decontamination waste. The plutonium purification process resulted in the discharge of large amounts of liquid organic chemicals in addition to aqueous solutions. This organic liquid, once in contact with groundwater, slowly dissolves and produces contaminant plumes. The presence of nonaqueous liquid has a major impact on the site's groundwater remediation strategy because the organic liquid in the subsurface represents a continuing source of contamination that is very difficult to clean up. Groundwater contamination in the 300 Area resulted mainly from discharge of waste from fuel fabrication.

Liquid effluents discharged to the ground at Hanford Site facilities percolated downward through the unsaturated zone toward the water table. Radionuclide and chemical constituents move through the soil column and, in some cases, enter the groundwater. In some locations, sufficient water was discharged to saturate the soil column to the surface. Not all contaminants move at the same rate as the water in the subsurface. Chemical processes such as adsorption onto soil particles, chemical precipitation, and ion exchange slow the movement of some constituents such as strontium-90, cesium-137, and plutonium-239/240. However, these processes may be affected by the chemical characteristics of the

**Table 6.1.1. Chemical and Radiological Groundwater Contaminants and Their Link to Site Operations**

| Areas | Facilities Type | Contaminants Generated |
|---|---|---|
| 100 | Reactor operations | Tritium, $^{60}Co$, $^{90}Sr$, $Cr^{6}$, $SO_4^{-2}$ |
| 200 | Irradiated fuel processing | Tritium, $^{90}Sr$, $^{99}Tc$, $^{129}I$, $^{137}Cs$, Pu, U, $CN^{-}$, $Cr^{6}$, $F^{-}$, $NO_3^{-}$ |
| 200 | Plutonium purification | Pu, carbon tetrachloride, chloroform, $NO_3^{-}$ |
| 300 | Fuel fabrication | $^{99}Tc$, U, $Cr^{6}$, trichloroethylene |

waste such as high ionic strength, acidity, or presence of chemical complexants. Other radionuclides, such as technetium-99, iodine-129, and tritium, and chemicals, such as nitrate, are not as readily retained by the soil and move vertically through the soil column at a rate nearly equal to the infiltrating water. When the contaminants reach the water table, their concentrations are reduced by dilution with groundwater. As these dissolved constituents move with the groundwater, many radionuclides and chemicals adhere to sediment particle surfaces (adsorption) or diffuse into the particles (absorption). Radionuclide concentrations are also reduced by radioactive decay.

Outside the source areas (i.e., liquid disposal sites), there is typically little or no downward gradient (driving force or head), so contamination tends to remain in the upper part of the aquifer. In the source areas, where large volumes of wastewater were discharged, a large vertical hydraulic gradient developed that moved contaminants downward in the aquifer. Layers of low-permeability silt and clay within the unconfined aquifer also limit the vertical movement of contaminants. Flow in the unconfined aquifer is generally toward the Columbia River, which acts as a drainage area for the groundwater flow system at Hanford. Contamination that reaches the river is further diluted by river water.

## 6.1.4 Groundwater Modeling

Numerical modeling of groundwater flow and contaminant transport is performed to simulate future groundwater flow conditions and predict the migration of contaminants through the groundwater pathway. Modeling of Hanford Site groundwater is also used to assess performance of waste disposal facilities and evaluate remediation strategies. In 1999, efforts were made to consolidate sitewide groundwater models into one model. The purpose of the consolidation was to eliminate redundancies and promote consistency in groundwater modeling analyses for the Hanford Site. The scope of the model consolidation process was to define needs and requirements of a sitewide model, evaluate current sitewide models and codes, and specify recommendations for a consolidated sitewide model. The recommendations for the consolidated sitewide model were subjected to an external peer review.

DOE selected a computer model developed by Pacific Northwest National Laboratory's groundwater project for the sitewide groundwater model. The model has broad capabilities to meet the anticipated needs of the site. Capabilities of the model include a high level of resolution, a large areal extent to address the potential movement of contaminant plumes off the Hanford Site, and the effects of natural recharge. The DOE selected the Coupled Fluid, Energy, and Solute Transport (CFEST-96) code as an interim code for implementing the consolidated sitewide groundwater model (Gupta 1997). The CFEST-96 code was developed by CFEST Co., Irvine, California. The model includes up to nine layers above the top of basalt to represent the major hydrogeologic units within the unconfined aquifer system.

In 1999, the sitewide model was applied to an environmental impact statement for solid waste. The Pacific Northwest National Laboratory used the sitewide groundwater model to predict the impact of water quality on human health and the environment. The purpose of this analysis was to calculate contaminant concentrations in groundwater from source areas defined in each of the environmental impact alternatives. The calculations were compared with drinking water standards and provided a basis to estimate the potential risk to human health and ecology. The potential sources of groundwater contamination were solid and radioactive waste contained in low-level burial grounds in the 200-East and 200-West Areas.

Groundwater models were used to assess the performance of groundwater pump-and-treat

systems in operable units in the 100-K, 100-N, 100-D, 100-H, and 200-West Areas. The operable units and their associated contaminants of concern are presented in Table 6.1.2. In these pump-and-treat systems, contaminated water is removed by means of extraction wells, treated, and either disposed of to the State-Approved Land Disposal Site or returned upgradient to the aquifer through injection wells. The models were used to predict system performance and progress toward remediation goals. The modeling was used to evaluate different extraction and injection well configurations, predict effects of pumping, assess the extent of hydraulic influence and the capture zone, and evaluate groundwater travel times. Modeling was conducted using the Micro-FEM© finite-element code developed by C. J. Hemker, Amsterdam, The Netherlands.

Computer modeling was used to evaluate hydraulic capture and optimize the pumping rates of the pump-and-treat systems in the operable units in the 100-K, 100-N, 100-D, and 100-H Areas. The modeling results showed that the extraction wells were reducing the net groundwater flow to the Columbia River through the targeted plume area by ~70% in the 100-KR-4 Operable Unit, ~96% in the 100-NR-2 Operable Unit, over 90% in the 100-D Area part of the 100-HR-3 Operable Unit, and ~82% in the 100-H Area part of the 100-HR-3 Operable Unit (DOE/RL-99-02; DOE/RL-99-13).

For the 200-UP-1 Operable Unit in the 200-West Area, modeling was performed to evaluate effectiveness in containing the targeted area of the technetium-99 and uranium plumes and track progress of remediation. The modeling showed that the area of high technetium-99 and uranium concentrations was captured and contained using one extraction well (299-W19-39). The extraction well removed at least one pore volume of water from the targeted plume area by the end of September 1999 (DOE/RL-99-02; DOE/RL-99-79). One pore volume is the total volume of pores considered collectively within soils of the targeted plume.

For the 200-ZP-1 Operable Unit in the 200-West Area, modeling was performed to evaluate the remedial action of the pump-and-treat system. The modeling results indicated that the pump-and-treat extraction wells contained the high carbon tetrachloride concentration area of the plume and provided a hydraulic barrier to plume movement (DOE/RL-99-79). The modeling predictions showed that pumping had removed one pore volume of water from the aquifer (upper 15 meters [49 feet]) near the northernmost extraction wells.

**Table 6.1.2. Operable Units and Associated Contaminants of Concern**

| Area | Operable Unit | Contaminants of Concern |
|---|---|---|
| 100-K | 100-KR-4 | Hexavalent chromium |
| 100-N | 100-NR-2 | Strontium-90 |
| 100-H and 100-D | 100-HR-3 | Hexavalent chromium |
| 200-West | 200-UP-1 | Technetium-99 and uranium |
| 200-West | 200-ZP-1 | Carbon tetrachloride |

## 6.1.5 Groundwater Monitoring

Groundwater monitoring at the Hanford Site is an integral part of the *Hanford Site Ground-Water Protection Management Plan* (DOE/RL-89-12, Rev. 2). That plan integrates monitoring at active waste disposal facilities to comply with requirements of the RCRA and Washington State regulations, as well as requirements for operational monitoring around reactor and chemical processing facilities and environmental surveillance monitoring. Pacific Northwest National Laboratory manages these monitoring efforts to assess the distribution and movement of existing groundwater contamination, to identify and characterize potential and emerging groundwater contamination problems, and to integrate the various groundwater projects to minimize redundancy.

The *Integrated Monitoring Plan for the Hanford Groundwater Monitoring Project* (PNNL-11989, Rev. 1) describes how the DOE will implement the groundwater monitoring requirements outlined in DOE (1987) and DOE/RL-89-12, Rev. 2. The purpose of the integrated monitoring plan is to 1) describe the monitoring well networks, constituents, sampling frequencies, and criteria used to design the monitoring program; 2) identify federal and state groundwater monitoring requirements and regulations; and 3) provide a list of wells, constituents, and sampling frequencies for groundwater monitoring conducted on the Hanford Site. Federal and state regulations include RCRA, CERCLA, and Washington Administrative Codes.

Information on contaminant distribution and transport are integrated into a sitewide evaluation of groundwater quality, which is documented in an annual groundwater monitoring report (e.g., PNNL-13116). Groundwater monitoring is also carried out during CERCLA cleanup investigations. These investigations, managed by Bechtel Hanford, Inc., are documented in annual summary reports (e.g., DOE/RL-99-79).

### 6.1.5.1 Groundwater Sampling and Analytes of Interest

Groundwater samples were collected from 645 wells for all monitoring programs during 1999. The locations of sampled wells are shown in Figures 6.1.8 and 6.1.9; well names are indicated only for those 400 and 600 Area wells specifically discussed in the text. Because of the density of unconfined aquifer wells in the operational areas, well names in these areas are shown on detailed maps in the following sections. Figure 6.1.10 shows the locations of facilities where groundwater monitoring was conducted to comply with RCRA (Appendix A in PNNL-13116). Wells at the Hanford Site generally follow a naming system that indicates the approximate location of the well. The prefix of the well name indicates the area of the site, as shown in Table 6.1.3. The names for 600 Area wells follow a local coordinate system in which the numbers indicate the distance relative to an arbitrary datum location in the south-central part of the site.

The monitoring frequency for the wells was selected by Pacific Northwest National Laboratory based on regulatory requirements, variability of historical data, proximity to waste sources, and characteristics of the groundwater flow system at the sample location. Of the 645 wells sampled, 288 were sampled once, 164 twice, 55 three times, 88 four times, and 50 wells were sampled more than four times during the year. Beginning in 1998, the sampling frequency was changed to every 3 years for several wells that showed concentrations with steady historical trends. Wells showing larger variability are sampled more frequently (annually or more often). Wells that monitor source areas are sampled more frequently than wells that do not monitor source areas. Contaminants with greater mobility

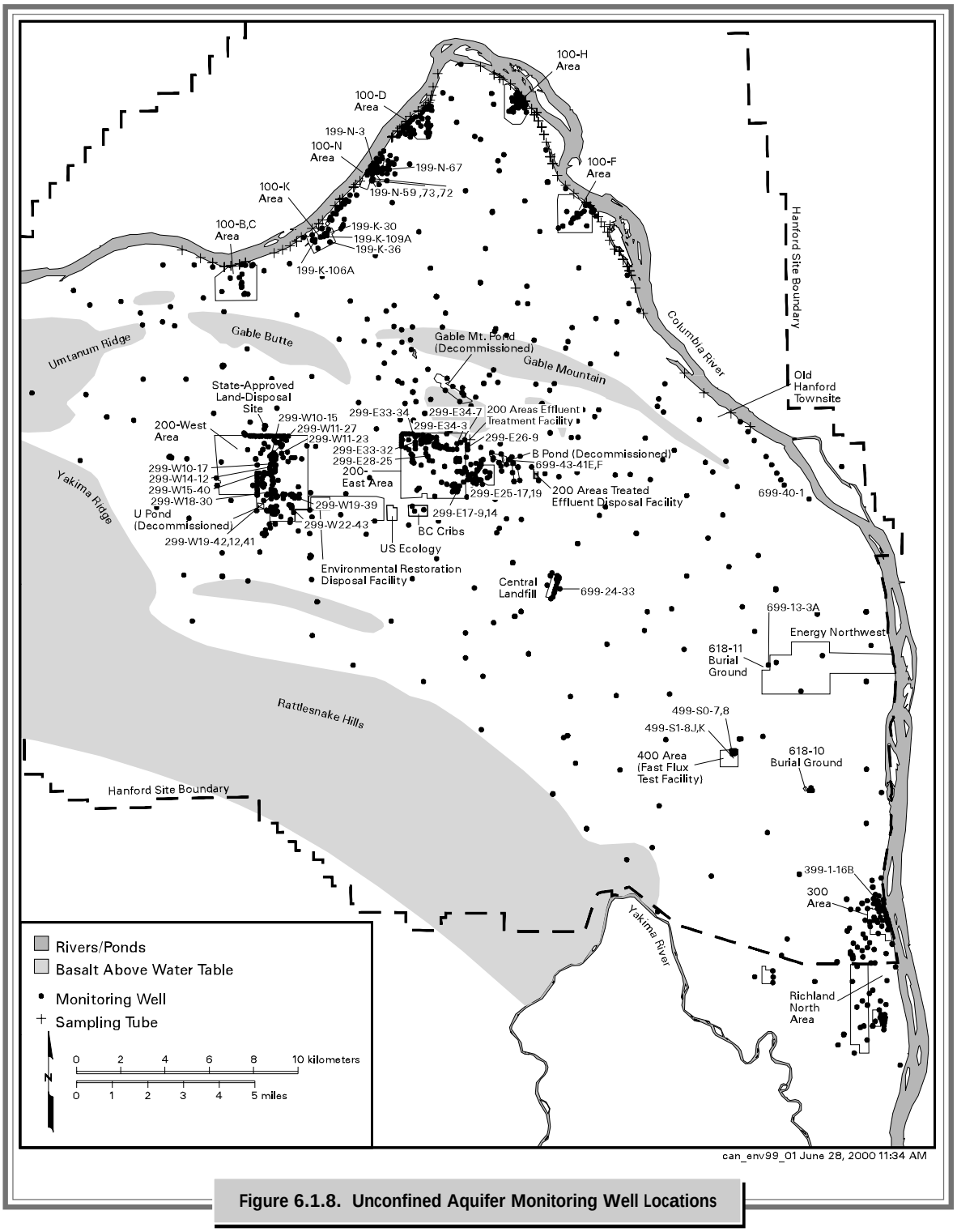


**Figure 6.1.8. Unconfined Aquifer Monitoring Well Locations**

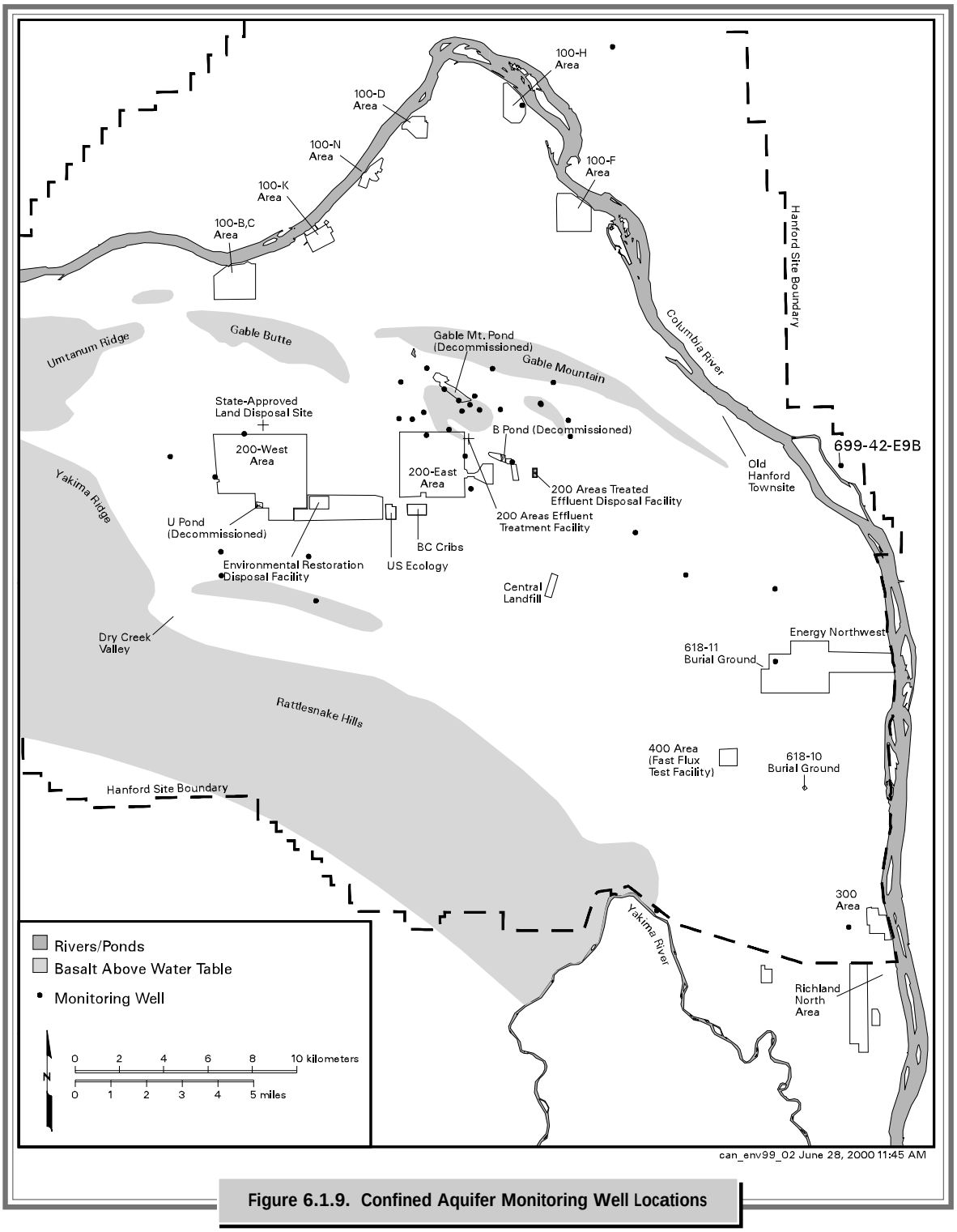


**Figure 6.1.9. Confined Aquifer Monitoring Well Locations**

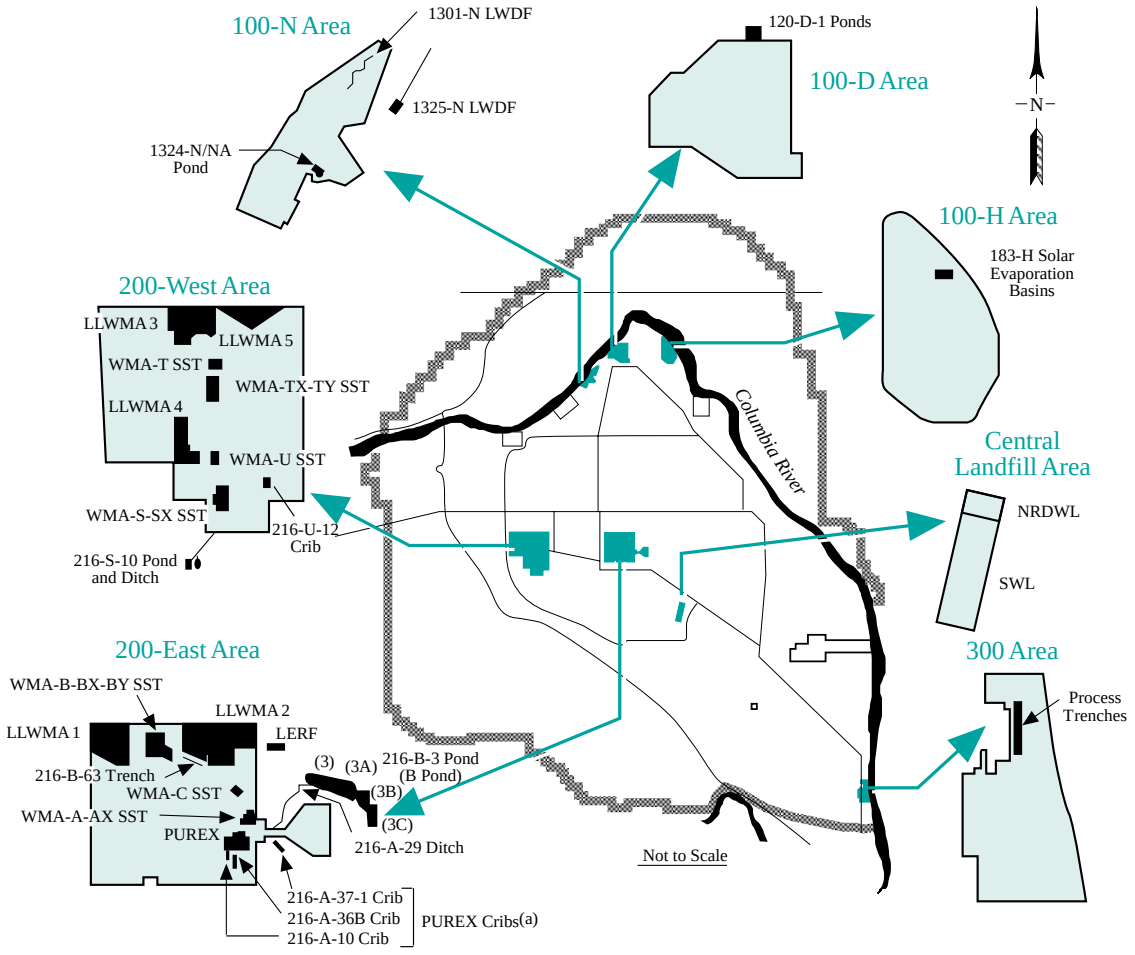


**Figure 6.1.10. Locations of RCRA Groundwater Monitoring Projects**

(e.g., tritium) in groundwater may be sampled more frequently than contaminants that are not very mobile (e.g., strontium-90).

Each monitoring program has access to groundwater data collected by other programs through a common database, the Hanford Environmental Information System. This database contains more than 1.6 million groundwater monitoring result records. After the data are verified and/or validated, they are made available to federal and state regulators for retrieval.

Most groundwater monitoring wells on the site are 10 to 20 centimeters (4 to 8 inches) in diameter. Monitoring wells for the unconfined aquifer are constructed with well screens or perforated casing generally in the upper 3 to 6 meters (10 to 20 feet) of

**Table 6.1.3. Hanford Site Well Naming System**

| Example Well Name | Area |
|---|---|
| **199-** | **100 Areas** |
| 199-B3-47 | 100-B,C Area |
| 199-D5-12 | 100-D Area |
| 199-F8-3 | 100-F Area |
| 199-H4-3 | 100-H Area |
| 199-K-30 | 100-K Area |
| 199-N-67 | 100-N Area |
| **299-** | **200 Areas** |
| 299-W19-3 | 200-West Area |
| 299-E28-4 | 200-East Area |
| **399-** | **300 Area** |
| 399-1-17A | 300 Area |
| **499-** | **400 Area** |
| 499-S1-8J | 400 Area |
| **699-** | **600 Area** |
| 699-50-53A | 600 Area north and west of datum |
| 699-42-E9A | 600 Area north and east of datum |
| 699-S19-11 | 600 Area south and west of datum |
| 699-S19-E13 | 600 Area south and east of datum |

Note: Letters at end of well names distinguish either multiple wells located close together or multiple intervals within a single well bore.

the unconfined aquifer, with the open interval extending across the water table. This construction allows sample collection at the top of the aquifer, where maximum concentrations of radionuclides and maximum concentrations of chemicals tend to be found. Wells monitoring the shallowest of the basalt-confined aquifers have screens, perforated casing, or an open hole within the monitored aquifer. Wells drilled before 1985 were generally constructed with carbon steel casing. Since 1985, RCRA monitoring wells and CERCLA characterization wells have been constructed with stainless steel casing and screens. Most monitoring wells on the site are sampled using either submersible or Hydrostar™ pumps (a registered trademark of Instrumentation Northwest, Inc., Redmond, Washington), though some wells are sampled with bailers or airlift systems.

Samples were collected for all programs following documented sampling procedures (PNL-6894, Rev. 1; ES-SSPM-001) based on U.S. Environmental Protection Agency (EPA) guidelines (OSWER 9950-1). Analytical techniques used are listed in DOE/RL-91-50, Rev. 2; PNNL-13080; and CERCLA work plans. The samples were analyzed for the radionuclides and chemicals listed in Table 6.1.4.

Most groundwater samples collected on the site in 1999 were analyzed for tritium. Selected samples were analyzed for other radionuclides. Sample results for radionuclides are generally presented in picocuries per liter; however, the results for total uranium, which is usually measured by laser fluorescence, are given in micrograms per liter.

Nitrate analyses were performed on many samples collected during 1999 because of the extensive areas with elevated nitrate concentrations that originate from onsite and offsite sources. However, nitrate concentrations were below the EPA 45-mg/L drinking water standard (40 CFR 141) for most of the affected area. Selected monitoring wells were used for additional chemical surveillance.

## 6.1.5.2 Data Interpretation

Each analysis of a groundwater sample provides information on the composition of groundwater at one time at one location in the aquifer. Uncertainty in the analyses results from a number of sources. Some of the sources of uncertainty are discussed below. Several techniques used to interpret the sample results are also discussed.

Groundwater sampling techniques are designed to collect a sample that is representative of the constituent concentration in the aquifer when the sample is taken. However, there are limitations in collecting representative samples or even defining

**Table 6.1.4. Radionuclides and Chemicals Analyzed for in Groundwater, 1999**

| Radiological Parameters | Chemical and Biological Parameters |
|---|---|
| Tritium | pH (field) |
| Beryllium-7 | Conductance (field and laboratory) |
| Carbon-14 | Total dissolved solids |
| Potassium-40 | Alkalinity |
| Cobalt-58 | Total carbon |
| Iron-59 | Total organic carbon |
| Cobalt-60 | Total organic halogens |
| Strontium-90 | Be, Na, Mg, Al, K, Co, Si, As, Se |
| Technetium-99 | Ca, V, Cr, Mn, Fe, Ni, Pb, Li, Hg |
| Ruthenium-106 | Cu, Zn, Sr, Ag, Cd, Sb, Ba, Sn, Tl, Ti |
| Antimony-125 | $F^-$, $Cl^-$, $NO_3^-$, $PO_4^{-3}$, $SO_4^{-2}$, $NO_2^-$, $Br^-$ |
| Iodine-129 | $CN^-$ |
| Cesium-134 | $NH_4^+$ |
| Cesium-137 | Hexavalent chromium |
| Neptunium-237 | Volatile organic compounds |
| Americium-241 | Semivolatile organic compounds |
| Gross alpha | Polychlorinated biphenyls |
| Gross beta | Pesticides |
| Europium isotopes | Chemical oxygen demand |
| Plutonium isotopes | Coliform bacteria |
| Radium isotopes | Dissolved oxygen (field) |
| Uranium isotopes | Total petroleum hydrocarbons |
| Uranium (total) | Oil and grease |
| | Diesel oil |
| | Gasoline |

precisely the volume of the aquifer represented by the sample. Proper well construction and maintenance, well purging, sample preservation, and, in some instances, filtering are used to help ensure consistent and representative samples. Careful sample labeling protocols, chain-of-custody documentation, and bottle preparation avoid many gross errors in sample results. Duplicate samples and field blanks are used to assess the sampling procedure.

Uncertainties are inherent in laboratory analysis of samples. Gross errors can be introduced in the laboratory or during sampling. Gross errors include transcription errors, calculation errors, mislabeling results, field equipment problems, or other errors that result from not following established procedures. Often, these gross errors can be recognized because unreasonably high or unreasonably low values result. Data review protocols are used to investigate and correct gross errors.

Random errors are unavoidably introduced in the analytical procedures. Usually, there are insufficient replicate analyses to assess the overall random error at each sample location. Instruments for analysis of radioactive constituents count the number of radioactive decay products at a detector, and background counts are subtracted. The nature of

radioactive decay and the instrument design result in a random counting error that is reported with the analytical result. Generally, a sample result less than the counting error indicates the constituent was not detected. The background subtraction may result in the reporting of results that are less than zero. Although below-zero results are physically impossible, the negative values are of use for some statistical analyses (see "Helpful Information" section for more details).

Systematic errors may result from problems with instrument calibration, standard or sample preparation, chemical interferences in analytical techniques, as well as sampling methodology and sample handling. Sample and laboratory protocols have been designed to minimize systematic errors. The analytical laboratories participate in interlaboratory comparisons, in which many laboratories analyze blind samples prepared by the EPA (see Section 8.0, "Quality Assurance").

In 1999, double-blind samples for specific constituents were analyzed (Section 8.0, "Quality Assurance," discusses double-blind results). Several wells were also cosampled with the Washington State Department of Health for comparison, and the results are available from that agency.

The chemical composition of groundwater may fluctuate from differences in the contaminant source, recharge, or groundwater flow field. The range of this concentration fluctuation can be estimated by taking many samples, but there is a limit to the number that can be practicably taken. Comparison of results through time helps interpret this variability.

Overall sample uncertainty may be factored into data evaluation by considering the concentration trend in a given well over time. This often helps identify gross errors, and overall, long-term trends can be distinguished from short-term variability. The interpretation of concentration trends depends on an understanding of chemical properties as well as site hydrogeology. The trend analysis, in turn, aids in refining the conceptual model of the chemical transport.

Plume maps presented in this section illustrate site groundwater chemistry. Although analytical data are available only at specific points where wells were sampled, contours are drawn to join the approximate locations of equal chemical concentration or radionuclide activity levels. The contour maps are simplified representations of plume geometry because of map scale, the lack of detailed information, and the fact that plume depth and thickness cannot be fully represented on a two-dimensional map. Plume maps are a powerful tool because knowledge of concentrations in surrounding wells, groundwater flow, site geology, and other available information are factored into their preparation.

## 6.1.6 Groundwater Monitoring Results

The following sections summarize the distribution of radioactive and chemical contaminants detected in Hanford Site groundwater during 1999. These discussions are followed by a summary of groundwater monitoring results for RCRA sites. More detailed information on groundwater monitoring, including listings of analysis results for each monitoring well in electronic format, is available in PNNL-13116. However, because PNNL-13116 (the annual groundwater report) covers the fiscal year, it does not include results from the last 3 months of 1999. This report includes results for the last 3 months of 1999.

One way to assess the impact of radionuclides and chemicals in groundwater is to compare them to EPA's drinking water standards and DOE's derived concentration guides (40 CFR 141 and DOE Order 5400.5; see Appendix C, Tables C.2 and C.5). The drinking water standards were established to protect public drinking water supplies. The derived

concentration guides were established to protect the public from radionuclides resulting from DOE operations. Specific drinking water standards have been defined for only a few radiological constituents. Drinking water standards have been calculated for other radionuclides, using an annual dose of 4 mrem/yr. Calculations of these standards consider their half-life, the energy and nature of the radioactive decay, and the physiological factors such as its buildup in particular organs. Drinking water standards are more restrictive than derived concentration guides because the standards are based on an annual dose of 4 mrem/yr to the affected organ. The guides are based on an effective dose equivalent of 100 mrem/yr (see Appendix C, Tables C.2 and C.5). In addition, the standards use older factors for calculating the concentrations that would produce a 4-mrem/yr dose than are used in calculating the guides. Thus, the values used below for standards are not always in agreement with the guides, which are available only for radionuclides. Primary and secondary drinking water standards are given for some chemical constituents; secondary standards are based on aesthetic rather than health considerations.

The total area of contaminant plumes with concentrations exceeding drinking water standards was estimated to be ~254 square kilometers (98 square miles) in 1999. This area, which is an increase of ~4% compared to 1998, occupies just under 20% of the total area of the Hanford Site. Most of the contaminant plume area lies southeast of the 200-East Area extending to the Columbia River (Figure 6.1.11). The most widespread contaminants within these plumes were tritium, iodine-129, technetium-99, uranium, strontium-90, carbon tetrachloride, nitrate, and trichloroethylene. Contaminant plumes with concentrations exceeding derived concentration guides occur in isolated areas. The only contaminants at levels above the derived concentration guide in 1999 were tritium, uranium, and strontium-90.

## 6.1.6.1 Radiological Monitoring Results for the Unconfined Aquifer

Hanford Site groundwater was analyzed for the radionuclides listed in Table 6.1.4. The distribution of tritium, iodine-129, technetium-99, uranium, strontium-90, carbon-14, cesium-137, cobalt-60, and plutonium are discussed in the following sections. Tritium and iodine-129 are the most widespread radiological contaminants associated with past site operations. Technetium-99 and uranium plumes are extensive in the 200 Areas and adjacent 600 Area. Strontium-90 plumes exhibit very high concentrations in the 100 Areas but are of relatively smaller extent. A carbon-14 plume is present in the 100-K Area. Cesium-137, cobalt-60, and plutonium contamination occurs in isolated areas in the 200 Areas. Gross alpha and gross beta are used as indicators of radionuclide distribution and are not discussed in detail because the specific radionuclides contributing to these measurements are discussed individually. Several other radionuclides, including ruthenium-106, antimony-125, and americium-241, are associated with wastes from Hanford Site operations. Because of their very low activities in groundwater, they are not discussed in this section. Half-lives of the radionuclides are presented in Table H.5 in the "Helpful Information" section.

**Tritium**. Tritium, which is present in irradiated nuclear fuel, was released in process condensates associated with decladding and dissolution of the fuel. Tritium was also manufactured as part of the Hanford mission by irradiating targets containing lithium in several reactors from 1949 to 1952 (DOE/EIS-0119F, WHC-SD-EN-RPT-004). In the late 1960s, tritium production took place in N Reactor (WHC-MR-0388).

Tritium was present in many historical waste streams at the Hanford Site and is highly mobile,

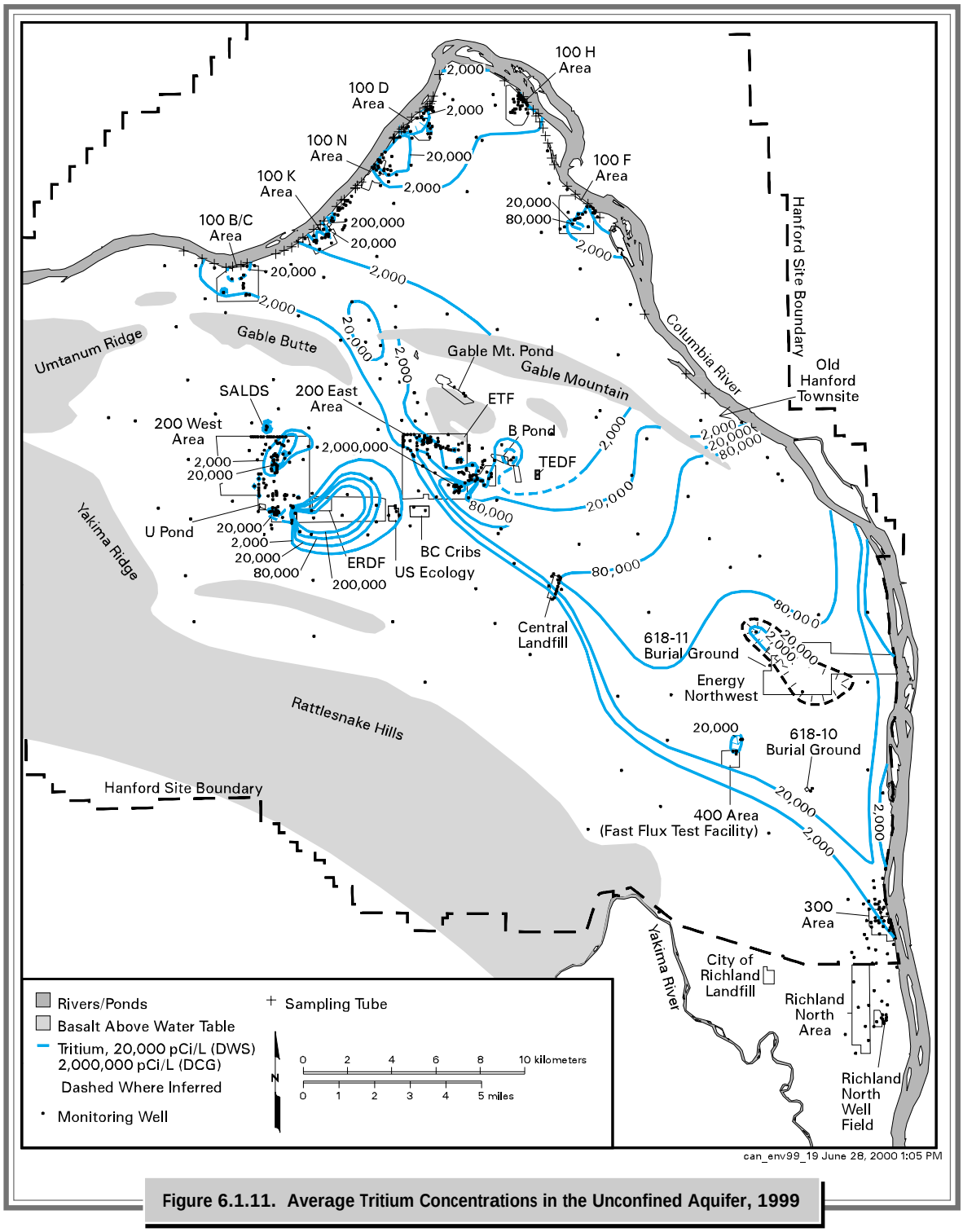


**Figure 6.1.11. Average Tritium Concentrations in the Unconfined Aquifer, 1999**

essentially moving at the same velocity as the groundwater. Consequently, the extent of groundwater contamination from site operations is generally reflected by tritium distribution. For this reason, tritium is the most frequently monitored radionuclide at the Hanford Site. Figure 6.1.11 shows the 1999 distribution of tritium in the unconfined aquifer. Tritium is one of the most widespread contaminants in groundwater across the Hanford Site and exceeded the 20,000-pCi/L drinking water standard in the 100, 200, 400, and 600 Areas. Tritium levels exceeded the 2,000,000-pCi/L derived concentration guide in the 100-K and 200 Areas. Tritium levels are expected to decrease because of dispersion and radioactive decay (half-life is 12.35 years). In the 600 Area, tritium was detected above the derived concentration guide for the first time in a well near the 618-11 burial ground in early 2000.

In 1999, the only tritium bearing liquid effluent discharged to the soil column on the Hanford Site occurred at the State-Approved Land Disposal Site, which began operating in 1995 and is located just north of the 200-West Area. The total radioactivity received by this facility in 1999 was ~9 curies, which was attributed solely to tritium.

***Tritium in the 100 Areas***. Tritium concentrations greater than the drinking water standard were detected in the 100-B,C, 100-D, 100-F, 100-K, and 100-N Areas. Tritium was detected above the derived concentration guide in the 100-K Area. The largest tritium plume in the 100 Areas with concentrations above the drinking water standard occurs along the Columbia River from the 100-N Area to the 100-D Area.

Tritium concentrations continued to exceed the drinking water standard in several wells in the northern and southwestern parts of the 100-B,C Area in 1999. Most of these are associated with past liquid disposal practices at 100-B,C retention basins and trenches near the Columbia River. The maximum tritium concentration decreased slightly to 86,900 pCi/L in the southwestern part of the 100-B,C Area.

In the 100-D Area, tritium concentrations decreased in the southwestern corner of the area, but were still greater than the drinking water standard in 1999. The maximum tritium reported during 1999 was 20,400 pCi/L in the southwestern corner of the area and is associated with the tritium plume that extends southwest to the 100-N Area.

One well in the 100-F Area contained tritium at concentrations greater than the drinking water standard. A maximum of 36,900 pCi/L occurred near the 118-F-1 burial ground in 1999. This was a slight decrease from the 1998 maximum. This burial ground received only solid waste, and the source of the tritium contamination is not known.

Well 199-K-30, located near the KE Reactor in the 100-K Area, continued to contain the highest tritium within the 100 Areas, with a maximum concentration of 2,230,000 pCi/L. This is the only tritium concentration in the 100 Areas that exceeded the derived concentration guide in 1999. The tritium trend for well 199-K-30 is shown in Figure 6.1.12. The probable source is past disposal to a French drain east of the reactor building (DOE/EIS-0119F). The downward migration of tritium is promoted by increased infiltration of water from the surface, which is discussed in PNNL-13116. Tritium levels greater than the drinking water standard, but much less than the derived concentration guide, occur in a small area near a pump-and-treat extraction well adjacent to the Columbia River.

A widespread tritium plume at levels exceeding the drinking water standard extends northeast from the northern part of the 100-N Area to the 600 and 100-D Areas. This plume is associated with past liquid disposal to the 1301-N and 1325-N Liquid Waste Disposal Facilities. The highest concentrations, which have decreased in recent years, continued to decrease in 1999. The maximum tritium level reported in the 100-N Area in 1999 was 51,600 pCi/L between the 1301-N facility and the Columbia River.

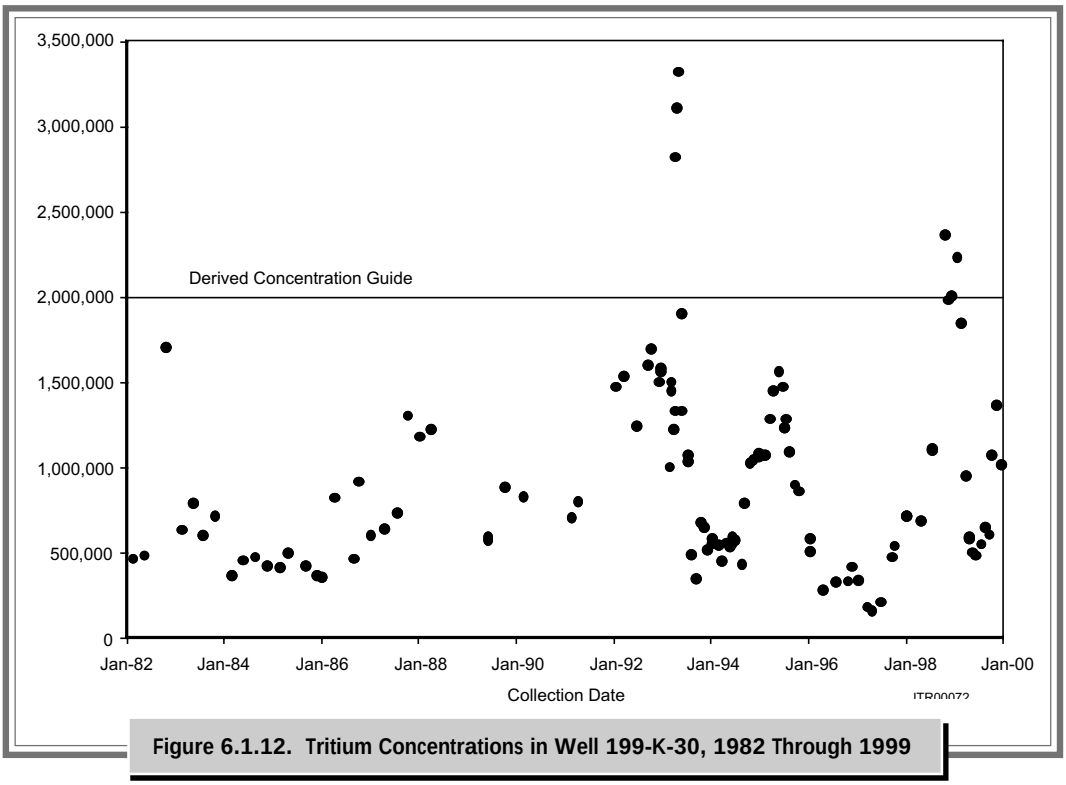


**Figure 6.1.12. Tritium Concentrations in Well 199-K-30, 1982 Through 1999**

***Tritium in the 200-East and 600 Areas***. The highest tritium concentrations in the 200-East Area continued to be measured in wells near cribs that received effluent from the Plutonium-Uranium Extraction Plant. However, tritium levels are generally decreasing slowly in this area because of dispersion and radioactive decay. Levels greater than the derived concentration guide were detected in only one well (299-E17-9) in 1999 in the 200-East Area. The maximum tritium level detected in this well, which monitors the 216-A-36B crib in the southeastern part of the 200-East Area, was 2,450,000 pCi/L. This was the highest tritium level detected in any well on the Hanford Site in 1999.

In the plume that extends from the southeastern portion of the 200-East Area, tritium concentrations above 200,000 pCi/L occurred in a small area downgradient of the Plutonium-Uranium Extraction Plant and did not extend beyond the 200-East Area boundary. The plume area at levels above 200,000 pCi/L has extended at least as far southeast as the Central Landfill in the recent past (PNL-8073).

A widespread tritium plume extends from the southeastern portion of the 200-East Area to the Columbia River (see Figure 6.1.11). Movement of the plume was consistent with patterns noted in recent monitoring reports (Section 5.10.3.2 in PNNL-12086, Section 2.9.2 in PNNL-13116). Separate tritium pulses associated with the two episodes of Plutonium-Uranium Extraction Plant operations can be distinguished in the plume. A trend plot (Figure 6.1.13) of the tritium concentrations in well 699-40-1 east of the 200-East Area near the shore of the Columbia River clearly shows the arrival of a pulse in the mid-1970s. High tritium concentrations near the Columbia River result from discharges to the ground during the operation of the Plutonium-Uranium Extraction Plant from 1956 to 1972. Following an 11-year shutdown, plant operation began in 1983 and ceased in December 1988.

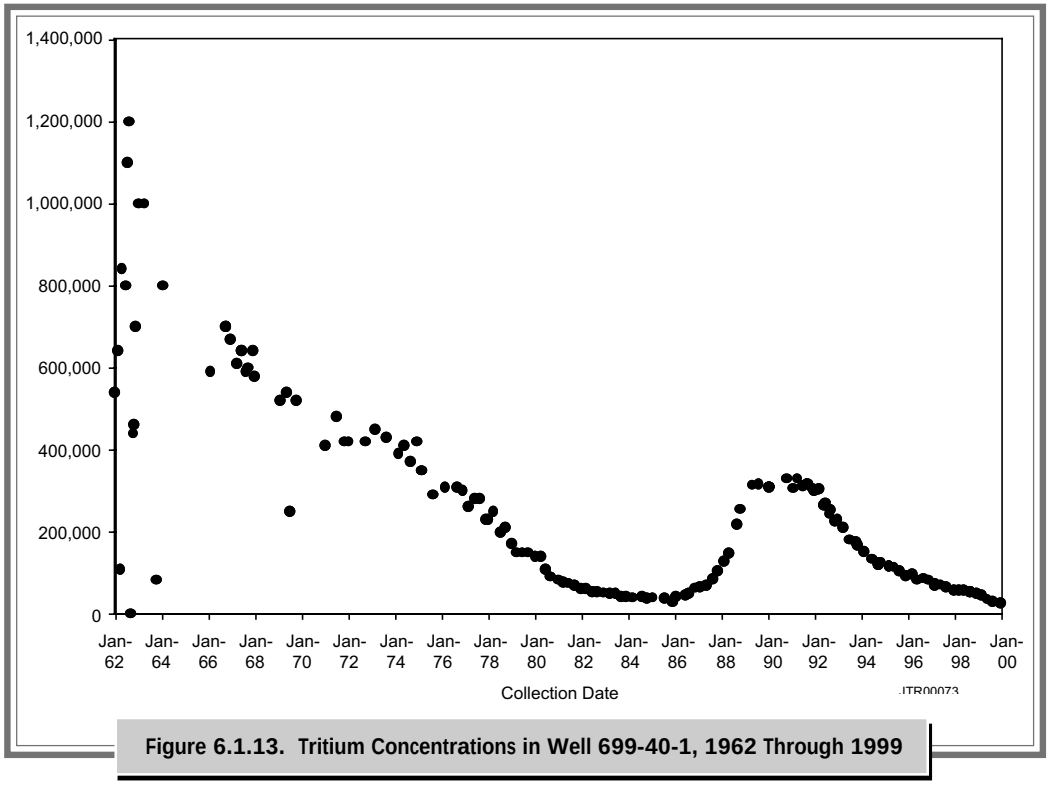


**Figure 6.1.13. Tritium Concentrations in Well 699-40-1, 1962 Through 1999**

This resulted in elevated tritium levels measured in several wells downgradient from the 200-East Area. Movement of the leading edge of this later pulse is evident near the Central Landfill (Figure 6.1.14), which shows arrival in early 1987. Tritium concentrations from the earlier pulse were at least three times the maximum concentrations in the later pulse. The effects of the 1983 to 1988 operational period have not been detected near the Columbia River.

The tritium plume, which has been monitored since the 1960s, provides information on the extent of groundwater contamination over time. Figure 6.1.15 shows the distribution of tritium in selected years from 1964 through 2000. This figure was created from maps in BNWL-90, BNWL-1970, PNL-5041, PNL-6825 (Section 5.0), PNNL-11141, and PNNL-13116. The contours in the original references were recalculated and interpreted to provide uniform contour intervals. Figure 6.1.15 shows that tritium at levels greater than the drinking water standard reached the Columbia River near the Old Hanford Townsite in approximately the mid-1970s. By the late 1980s, tritium at these levels was discharging to the Columbia River several kilometers south of the Old Hanford Townsite. The tritium plume continued to expand in the southeastern part of the Hanford Site. By 1995, tritium at concentrations exceeding 20,000 pCi/L was entering the Columbia River along greater portions of the shoreline extending between the Old Hanford Townsite and the 300 Area. Tritium levels did not change significantly between 1995 and 2000.

The configuration of the western portion of the tritium plume shown in Figure 6.1.11 closely matches previous predictions of the direction of contaminant movement from the 200-East Area (PNL-6328). Movement is forced to the south by flow that originates at the groundwater mound beneath the former B Pond. Flow to the southeast also appears to be controlled by a zone of highly permeable sediment, stretching from the 200-East

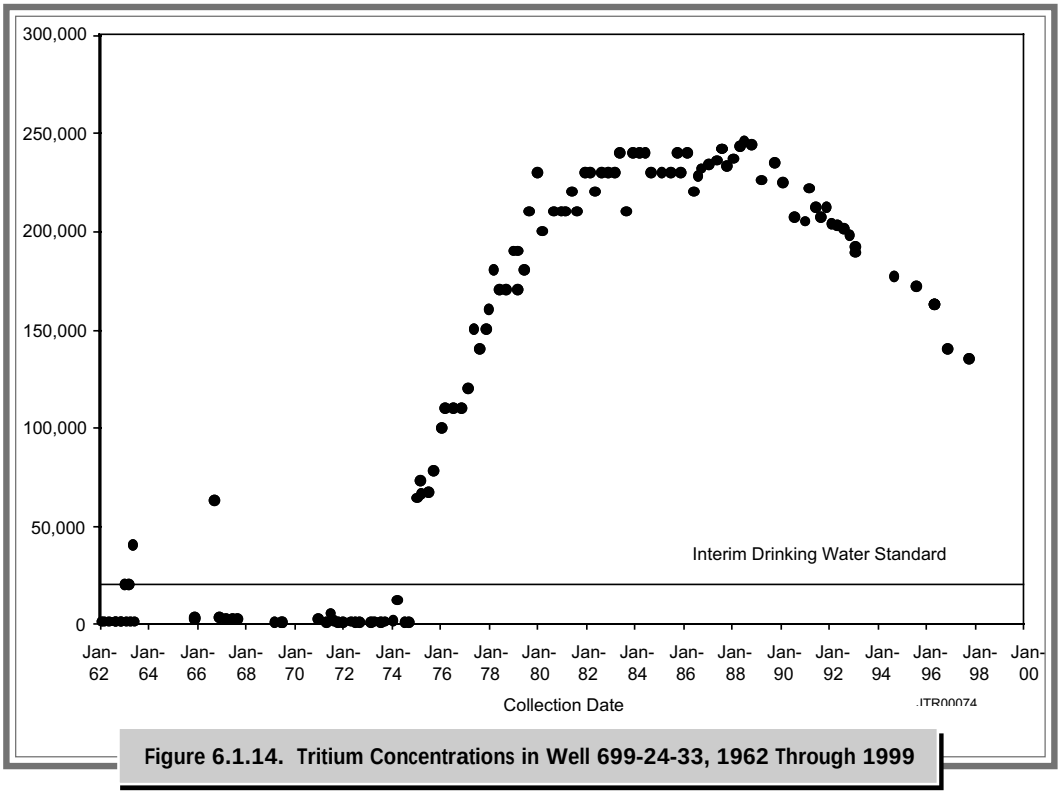


**Figure 6.1.14. Tritium Concentrations in Well 699-24-33, 1962 Through 1999**

Area toward the 400 Area (PNL-7144). The shape of the tritium plume indicates that tritium discharges to the Columbia River between the Old Hanford Townsite and the 300 Area.

In January 1999, a high tritium concentration of 1,860,000 pCi/L was measured in one well (699-13-3A) near the 618-11 burial ground. This burial ground is located west of the Energy Northwest reactor complex in the eastern 600 Area (see Figure 6.1.8). The high concentration was confirmed by re-analysis. A sample collected in January 2000 measured 8,100,000 pCi/L, which is the highest tritium concentration detected at the Hanford Site in recent years. The burial ground was active from 1962 to 1967 and received a variety of low and high level waste from the 300 Area. A special investigation is being conducted in year 2000 to define the source of the high tritium levels. The Phase I sampling results are reported in PNNL-13228 and are available on the Groundwater Monitoring Project website at http://www.hanford.pnl.gov/groundwater.

The distribution of tritium near the former B Pond shows an area of concentration above the drinking water standard in a limited area. B Pond produced a radial flow pattern of groundwater that mostly had low contaminant levels. The mound under the former pond has been dissipating since wastewater flow was diverted to the 200 Areas Treated Effluent Disposal Facility in August 1997.

Tritium is also found at levels above the drinking water standard in the northwestern part of the 200-East Area (see Figure 6.1.11). This plume appears to extend to the northwest through the gap between Gable Mountain and Gable Butte. The tritium distribution to the northwest and southeast of the 200-East Area indicates a divide in groundwater flow direction across the 200-East Area. A pulse of tritium levels above the drinking water standard also occurred between Gable Mountain and Gable Butte.

***Tritium in the 200-West Area***. Tritium from sources near the Reduction-Oxidation Plant forms

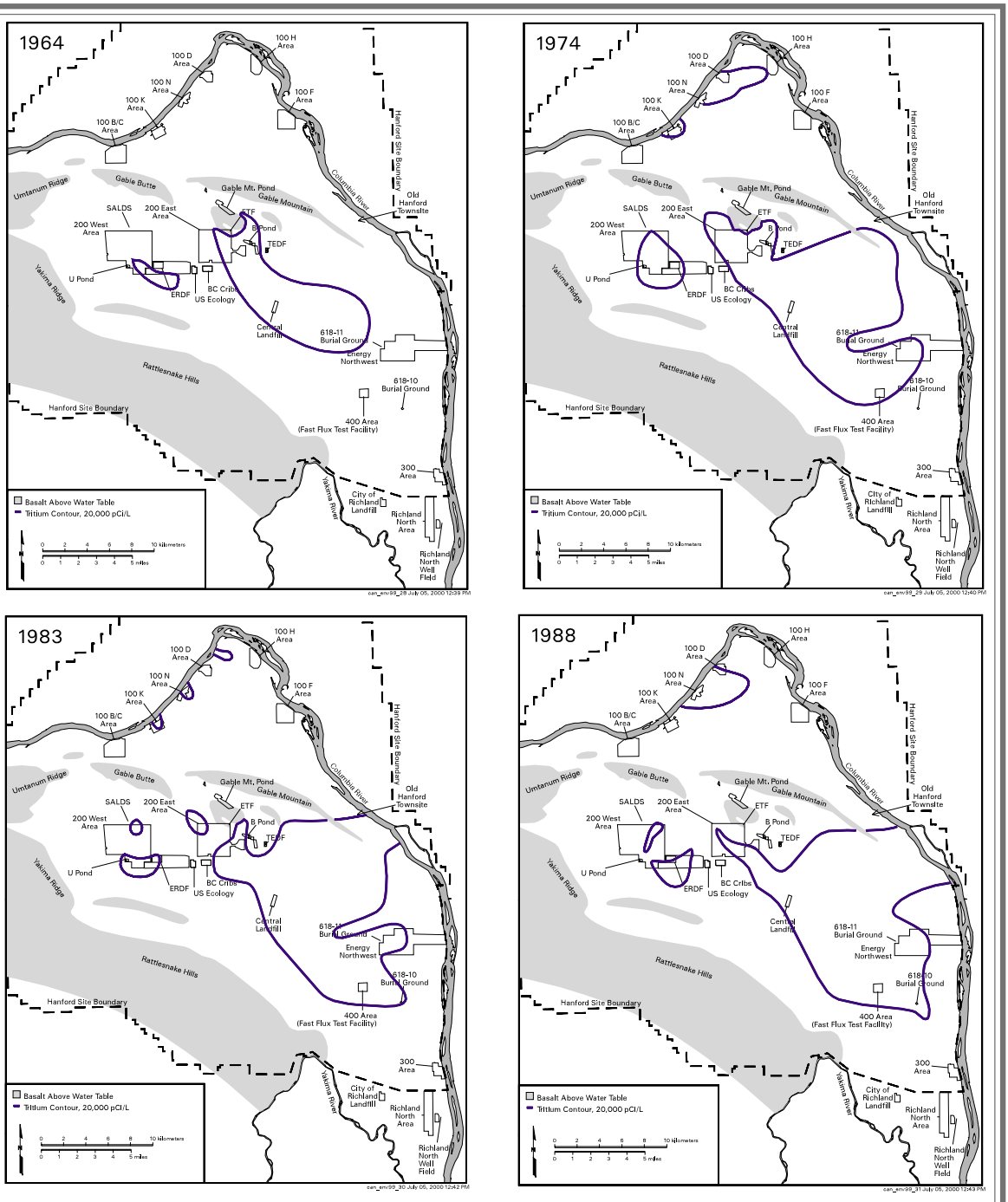


**Figure 6.1.15. Historical Tritium Concentrations on the Hanford Site**

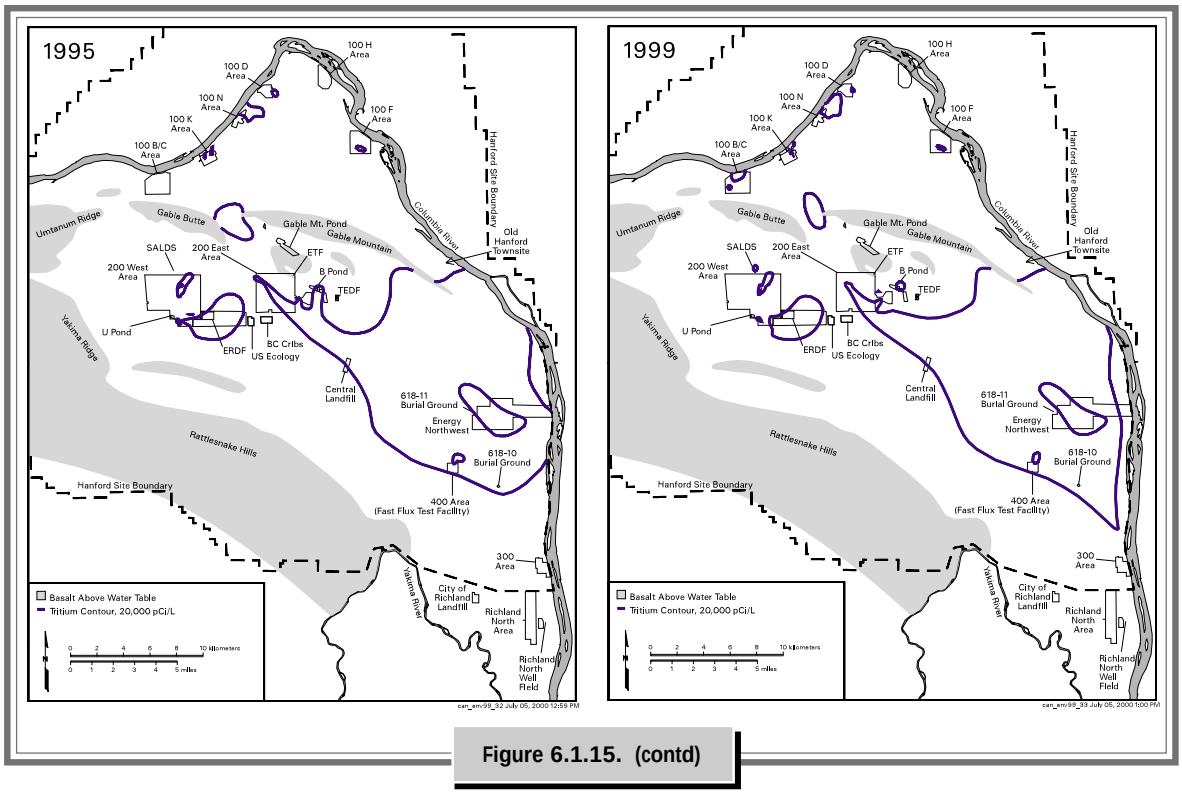


**Figure 6.1.15. (contd)**

the most extensive plume associated with the 200-West Area. The Reduction-Oxidation Plant is located in the southeastern part of the 200-West Area and operated from 1951 through 1967. This plume extends into the 600 Area east of the 200-West Area to US Ecology's facility (see Figure 6.1.11). The eastern part of the plume curves to the north, but the tritium concentrations in the northern part of the plume are declining. However, concentrations continue to increase slowly in the eastern part of the plume near the US Ecology facility. Tritium concentrations exceeded the drinking water standard in much of the plume, including a small area near the former 216-S-25 crib and S-SX tank farm upgradient of the Reduction-Oxidation Plant. The maximum concentration in this plume in 1999 was 408,000 pCi/L in the 600 Area east of the Reduction-Oxidation Plant. The movement of plumes in the 200-West Area is slow because the Ringold Formation sediment that underlies the area has low permeability and restricts flow. Movement of the plumes in the 200-West Area is also slow because of declining hydraulic gradients since the closure of U Pond in 1984. This pond was located near the southern boundary of the 200-West Area.

A smaller tritium plume covers much of the northern part of the 200-West Area and extends to the northeast (see Figure 6.1.11). This plume is associated with former T Plant waste sites, including TY tank farm, the 242-T evaporator, and inactive disposal cribs. The highest tritium concentration, detected just east of the TX and TY tank farms near the 216-T-26 crib, was equal to the derived concentration guide of 2,000,000 pCi/L. The area where the drinking water standard was exceeded extends northeast past the northern boundary of the 200-West Area.

Tritium concentrations were generally lower in 1999 than in 1998 at wells monitoring the State-Approved Land Disposal Site just north of the 200-West Area. The maximum concentration decreased from 2,100,000 pCi/L in 1998 to

610,000 pCi/L in 1999, which exceeded the drinking water standard. The lower concentrations in 1999 reflect the reduced concentration levels in effluent discharged to this facility over the past ~2 years (PNNL-13058). By the end of December 1999, ~304 curies of tritium and over 270 million liters (71.3 million gallons) of treated effluent containing tritium had been discharged to this facility since operations began in 1995.

***Tritium in the 300 Area***. The eastern portion of the tritium plume that emanates from the 200-East Area continues to move to the east-southeast and discharge into the Columbia River (see Figure 6.1.11). The southern edge of the tritium plume extends into the 300 Area, as shown in Figure 6.1.16. Figure 6.1.16 shows that tritium concentrations decrease from greater than 10,000 pCi/L in the northeastern part of the 300 Area to less than 100 pCi/L in the southwestern part of the 300 Area. This distribution is nearly the same as the 1998 distribution. Although tritium in the 300 Area is below the drinking water standard, a concern has been the potential migration of tritium to a municipal water supply to the south. The municipal water supply consists of the city of Richland's well field and recharge ponds (see Figure 6.1.16). The highest tritium level detected south of the 300 Area was 516 pCi/L near the well field. Monitoring data indicate that the Hanford Site tritium plume has not reached the municipal water supply.

The tritium plume is not expected to impact the well field because of the influence of groundwater flow from the Yakima River, recharge from agricultural irrigation, and recharge from infiltration ponds at the well field (see Figure 6.1.16). The Yakima River is at a higher elevation than the water table and recharges the groundwater in this area. Groundwater flows from west to east (see Figure 6.1.16), minimizing the southward movement of the contaminant plume. Recharge from agricultural irrigation occurs south of the Hanford Site boundary and contributes to eastward flow. The recharge ponds are supplied with Columbia River water, which infiltrates to the groundwater. The amount of recharge water exceeded the amount pumped at the well field by a factor of ~2:1 in 1999, resulting in groundwater flow away from the well field. Recharge creates a mound that further ensures that tritium-contaminated groundwater will not reach the well field.

***Tritium in the 400 Area***. The tritium plume that originated in the 200-East Area extends under the 400 Area. The maximum concentration detected in this area during 1999 was 33,800 pCi/L in well 499-S0-8, a backup water supply well. The average concentration in this well was ~15,200 pCi/L during 1999. Tritium levels appear to fluctuate annually, but the maximum levels have increased. Samples from another backup water supply well (499-S0-7) showed a maximum tritium concentration of 20,600 pCi/L. Tritium levels in the primary water supply well for the 400 Area (499-S1-8J) did not exceed the annual average drinking water standard of 20,000 pCi/L in 1999 and never exceeded 4,500 pCi/L in any one month. The water supply wells are located in the northern part of the 400 Area. Additional information on the 400 Area water supply is provided in Section 4.3, "Radiological Surveillance of Hanford Site Drinking Water."

Tritium levels below the drinking water standard north of the 400 Area are most likely due to discharge at the 400 Area process ponds (see Figure 6.1.11). A maximum tritium concentration of 20,400 pCi/L in a well near the process ponds is attributed to the 200-East Area tritium plume and not wastewater discharge to the ponds. The source of the wastewater is potable water from local water supply wells.

**Iodine-129**. Iodine-129 has a relatively low drinking water standard (1 pCi/L), has the potential for accumulation in the environment as a result of long-term releases from nuclear fuel reprocessing facilities (Soldat 1976), and has a long half-life (16,000,000 years). The relatively low fission yield for production of iodine-129 combined with its long half-life limits its specific activity in Hanford Site

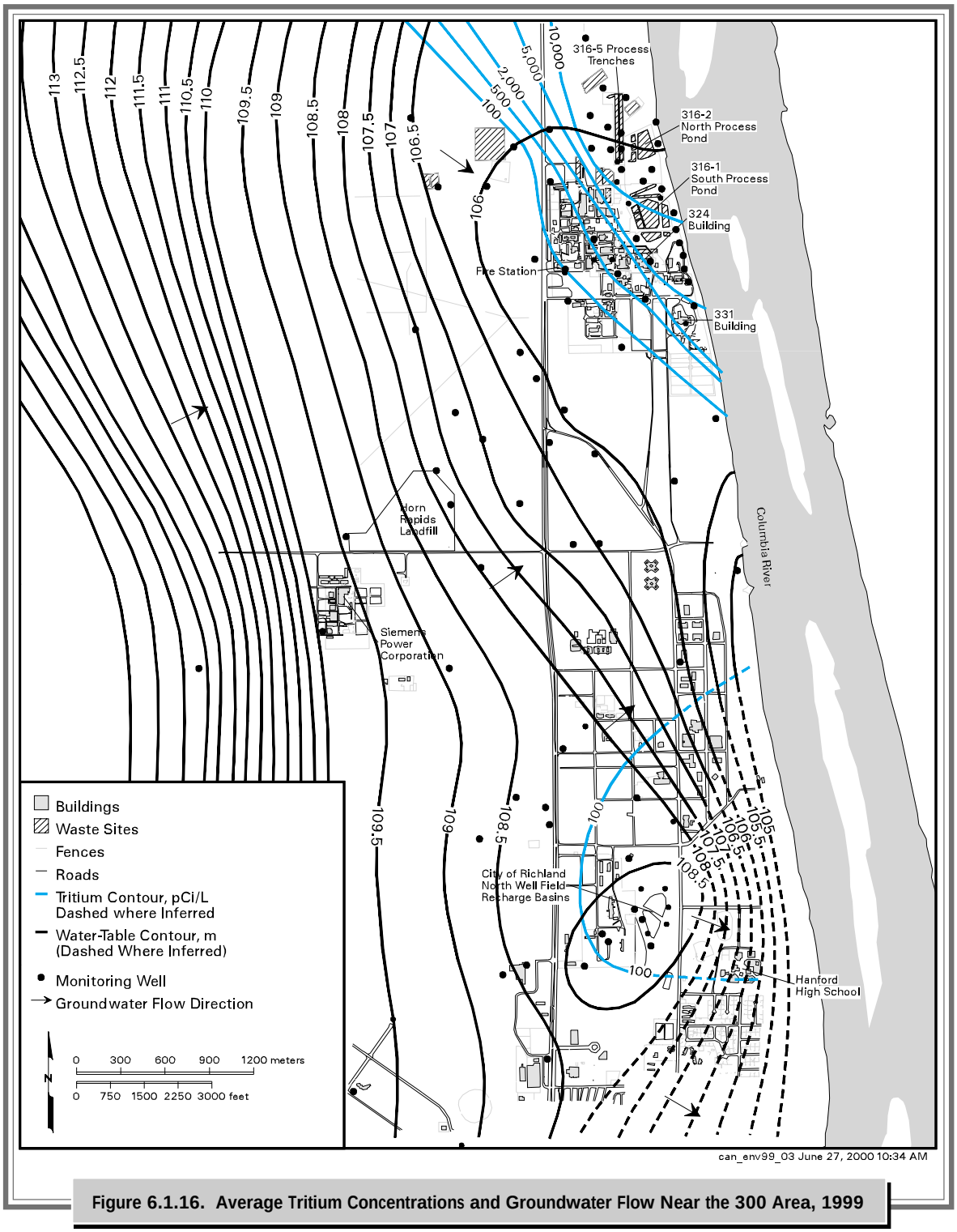


**Figure 6.1.16. Average Tritium Concentrations and Groundwater Flow Near the 300 Area, 1999**

wastes. Iodine-129 may be released as a vapor during fuel dissolution and during other elevated temperature processes and, thus, may be associated with process condensate wastes. At the site, the main contributor of iodine-129 to groundwater has been liquid discharges to cribs in the 200 Areas. Iodine-129 has essentially the same high mobility in groundwater as tritium. The iodine-129 plume at levels exceeding the drinking water standard is extensive in the 200 and 600 Areas. No groundwater samples showed iodine-129 concentrations above the 500-pCi/L derived concentration guide in 1999.

***Iodine-129 in the 200-East Area***. The highest iodine-129 concentrations in the 200-East Area are in the northwest near the BY cribs and in the southeast near the Plutonium-Uranium Extraction Plant (Figure 6.1.17). The maximum level of iodine-129 detected in 1999 in the 200-East Area was 12.1 pCi/L south of the Plutonium-Uranium Extraction Plant near the 216-A-36B crib. Iodine-129 concentrations are declining slowly or are stable. The iodine-129 plume extends from the Plutonium-Uranium Extraction Plant area southeast into the 600 Area and appears coincident with the tritium plumes (see Figure 6.1.11). The plume appears smaller than the tritium plume because of the lower initial concentration of iodine-129. The iodine-129 contamination can be detected as far to the east as the Columbia River but at levels below the drinking water standard. Data indicate that iodine-129 at levels above the drinking water standard is approaching the Columbia River (see Figure 6.1.17). The plume likely had the same sources as the tritium plume. Iodine-129 is also present in groundwater at levels above the drinking water standard in the northwestern 200-East Area; however, a definite source for this plume has not been determined. This plume extends northwest into the gap between Gable Mountain and Gable Butte.

***Iodine-129 in the 200-West Area***. The distribution of iodine-129 in Hanford Site groundwater is shown in Figure 6.1.17. The highest level observed in 1999 was 59.2 pCi/L near the T, TX, and TY tank farms in the northern part of the 200-West Area. This level occurs in a plume that originates near the tank farms and nearby disposal facilities and extends northeast toward T Plant. The iodine-129 plume is generally coincident with the technetium-99 and tritium plumes in this area. A much larger iodine-129 plume occurs in the southeastern part of the 200-West Area, which originates near the Reduction-Oxidation Plant, and extends east into the 600 Area. This plume is essentially coincident with the tritium plume, though there appears to be a contribution from cribs to the north near U Plant. In 1999, the maximum concentration detected in this plume was 37.7 pCi/L in the 600 Area east of the Reduction-Oxidation Plant. Iodine-129 levels in this plume did not change significantly between 1998 and 1999.

**Technetium-99**. Technetium-99, which has a half-life of 210,000 years, is produced as a high-yield fission byproduct and is present in waste streams associated with fuel reprocessing. Reactor operations may also result in the release of some technetium-99 associated with fuel element breaches. Technetium-99 is typically associated with uranium through the fuel processing cycle, but uranium is less mobile in groundwater. Under the chemical conditions that exist in Hanford Site groundwater, technetium-99 is normally present in solution as anions that sorb poorly to sediments. Therefore, technetium-99 is very mobile in site groundwater. The derived concentration guide is 100,000 pCi/L and the interim drinking water standard is 900 pCi/L for technetium-99.

Technetium-99 was found at concentrations greater than the 900-pCi/L interim drinking water standard in the 100-H, 200-East, and 200-West Areas, with the highest measured in the 200-West Area.

***Technetium-99 in the 100-H Area***. Technetium-99 concentration exceeded the interim drinking water standard in one well near the 183-H solar evaporation basins in the 100-H Area. The

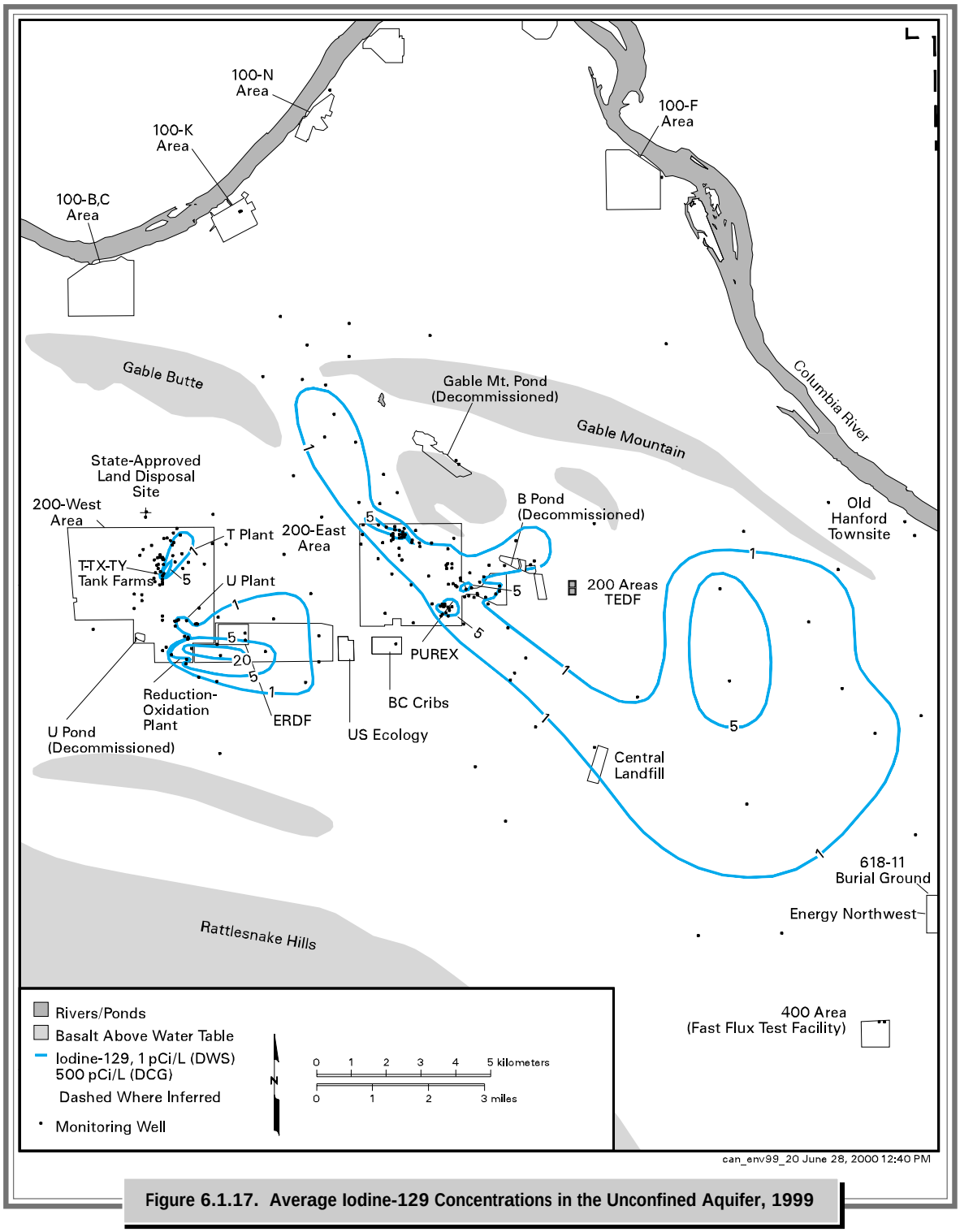


**Figure 6.1.17. Average Iodine-129 Concentrations in the Unconfined Aquifer, 1999**

technetium-99 concentration, which is influenced by fluctuations in Columbia River stage at this well, was 1,070 pCi/L in November 1999. Usually concentrations are highest when river stage is low.

***Technetium-99 in the 200-East Area***. Groundwater in the northwestern part of the 200-East Area and a part of the 600 Area north of the 200-East Area contains technetium-99 at concentrations above the interim drinking water standard (Figure 6.1.18). The source of these two technetium plumes was apparently the BY cribs (Section 2.9.1 in PNNL-13116). However, some of this contamination is believed to originate from tank farms B, BX, and BY (PNNL-11826). Technetium-99 concentrations continued to increase in several wells monitoring tank farms B, BX, and BY in 1999. The maximum concentration in the 200-East Area occurred at the BY cribs at a level of 9,410 pCi/L. The maximum technetium-99 concentration in the plume north of the 200-East Area in 1999 was 2,820 pCi/L. This plume appears to be moving through the gap between Gable Mountain and Gable Butte. Technetium-99 levels are increasing in some of the wells in this plume.

***Technetium-99 in the 200-West Area***. The largest technetium-99 plume in the 200-West Area originates from cribs that received effluent from U Plant and extends into the 600 Area to the east (Figure 6.1.19). The technetium plume is approximately in the same location as the uranium plume because technetium-99 and uranium, which are typically associated with the same fuel reprocessing cycle, were disposed to the same 216-U-1, 216-U-2, and 216-U-17 cribs. The highest technetium-99 concentrations in this plume in 1999 were measured in several wells in vicinity of the 216-U-17 crib, where remediation by a pump-and-treat method is occurring (see below). The high concentration portion of the plume, which has decreased in size, appears to be moving downgradient toward the extraction center (well 299-W19-39). The maximum level was detected in monitoring well 299-W19-29 at a level of 28,900 pCi/L. This well is located approximately midway between the 216-U-1, 216-U-2, and the 216-U-17 cribs.

The purpose of the 200-UP-1 pump-and-treat system near the 216-U-17 crib is to contain and reduce the highest concentrations in the technetium-99 and uranium plumes (Record of Decision 1997). As of September 1999, ~61.7 grams (2.2 ounces) of technetium-99 have been removed from ~357 million liters (99 million gallons) of extracted groundwater since pump-and-treat operations began in 1994 (DOE/RL-99-79). This mass of technetium-99 is equivalent to ~1.1 curie of radioactivity. Contaminated groundwater is currently pumped from one extraction well (299-W19-39) and transported via pipeline to the 200 Areas Effluent Treatment Facility, where it is treated using a number of processes. The treated groundwater is disposed of to the State-Approved Land Disposal Site north of the 200-West Area.

Several wells that monitor tank farms T, TX, and TY consistently showed technetium-99 concentrations above the interim drinking water standard in 1999 (see Figure 6.1.19). The highest was 6,200 pCi/L east of the TX and TY tank farms, where technetium-99 levels have been increasing in recent years. These increases may be related to changes in the direction of groundwater flow being influenced by the 200-ZP-1 pump-and-treat operation immediately south of the tank farms. In the northeastern corner of T tank farm, technetium-99 levels were above the interim drinking water standard in two wells. The maximum in this area was 7,110 pCi/L in 1999. This was a decrease from the maximum of 13,000 pCi/L in 1998. The sources of the technetium-99 contamination were tank farms T, TX, and TY (PNNL-11809).

Technetium-99 contamination in small areas in the southern part of the 200-West Area originates near tank farms S and SX and the 216-S-13 crib. Multiple sources of technetium-99 contribute to

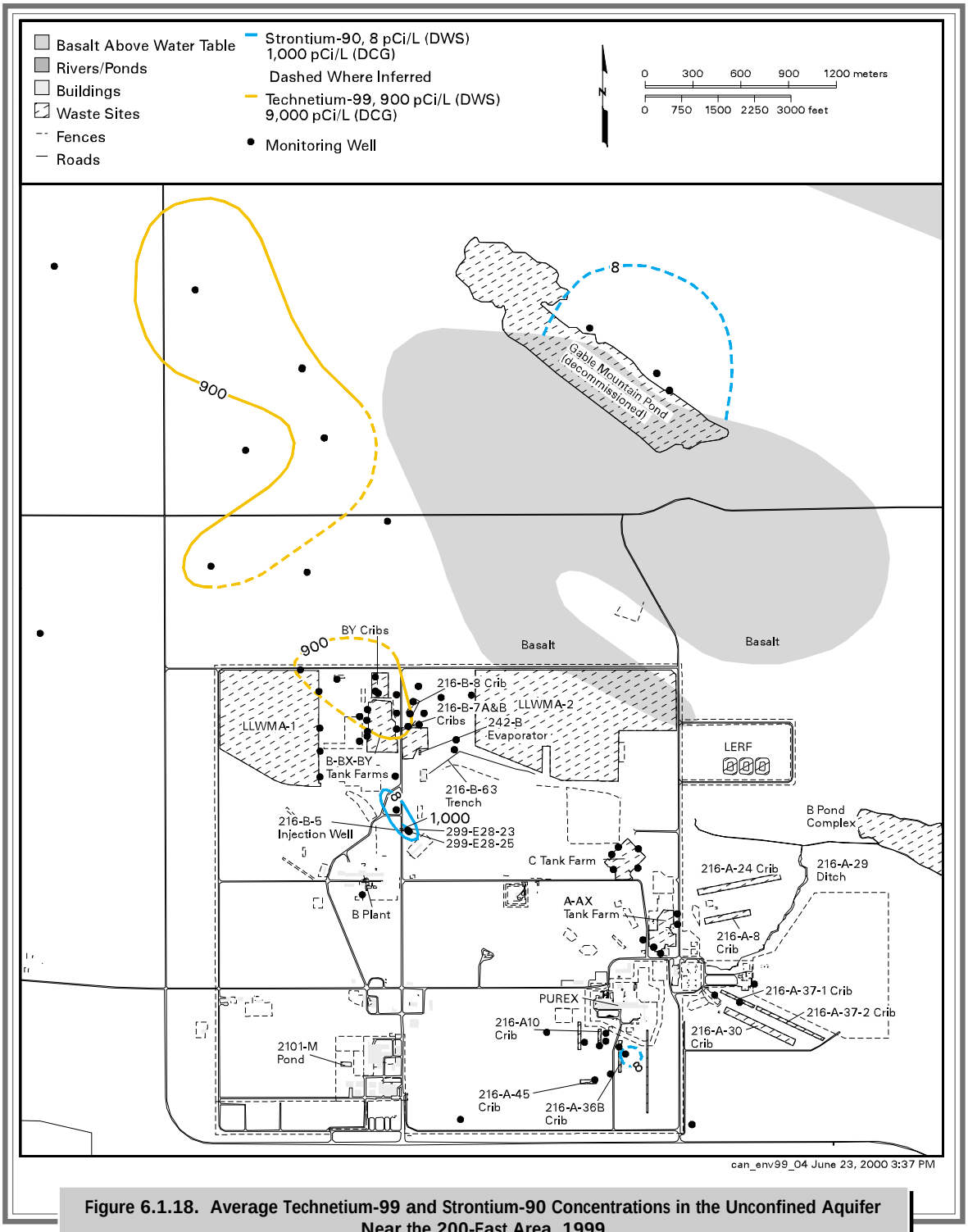


**Figure 6.1.18. Average Technetium-99 and Strontium-90 Concentrations in the Unconfined Aquifer Near the 200-East Area, 1999**

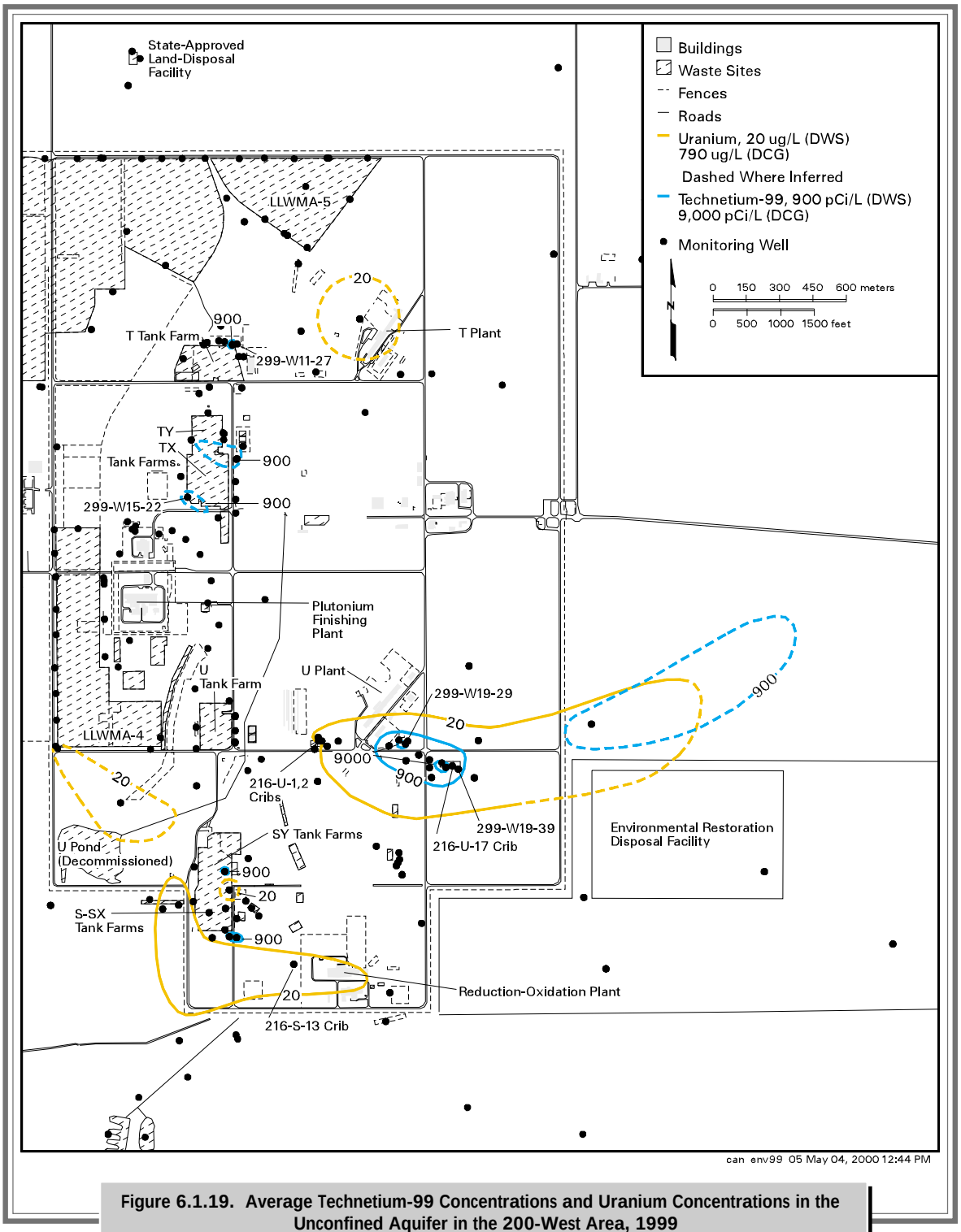


**Figure 6.1.19. Average Technetium-99 Concentrations and Uranium Concentrations in the Unconfined Aquifer in the 200-West Area, 1999**

groundwater contamination in this area (PNNL-11810). The maximum level detected was 48,600 pCi/L in a new well in the southwestern corner of tank farm SX. This was the highest technetium-99 concentration detected on the Hanford Site in 1999.

**Uranium**. There were numerous possible sources of uranium released to the groundwater at the Hanford Site, including fuel fabrication, fuel reprocessing, and uranium recovery operations. Uranium may exist in several states, including elemental uranium or uranium oxide as well as tetravalent and hexavalent cations. Only the hexavalent form has significant mobility in groundwater, largely by forming dissolved carbonate species. Uranium mobility is thus dependent on oxidation state, pH, and the presence of carbonate. Uranium is observed to migrate in site groundwater but is retarded relative to more mobile species such as technetium-99 and tritium. The EPA's proposed drinking water standard for uranium is 20 μg/L, which is based on chemical toxicity. The derived concentration guide that represents an annual effective dose equivalent of 100 mrem/yr is 790 μg/L for uranium.

Uranium has been detected at concentrations greater than the proposed drinking water standard in portions of the 100, 200, 300, and 600 Areas. The highest levels detected at the Hanford Site in 1999 were in the 200-West Area near U Plant, where uranium levels exceeded the derived concentration guide.

***Uranium in the 100 Areas***. One well near F Reactor continues to show elevated uranium levels. However, the concentration fell below the 20-μg/L proposed drinking water standard to 19.5 μg/L in 1999.

Uranium was detected at levels higher than the proposed drinking water standard in three wells in the 100-H Area. Uranium concentrations in the 100-H Area usually fluctuate in response to changes in groundwater levels. The maximum detected in 1999 was 157 μg/L downgradient of the 183-H solar evaporation basins. Past leakage from the basins is the source of the 100-H Area uranium contamination. These basins were remediated in 1996. Remediation consisted of demolition and removal of the basins and removal of the underlying contaminated soil.

***Uranium in the 200-East Area***. In the 200-East Area, uranium contamination at levels greater than the proposed drinking water standard is limited to isolated areas associated with B Plant. The uranium distribution in 1999 indicates the highest concentrations were in the vicinity of the B, BX, and BY tank farms; BY cribs; and 216-B-5 injection well that has been inactive since 1947. The highest concentration detected was 350 μg/L east of the BY tank farm (southeast of the BY cribs). The source of the uranium contamination in this area is unclear. Near inactive injection well 216-B-5, one well annually shows an increasing uranium concentration greater than the proposed drinking water standard; however, this well was not sampled in 1999. The sampling schedule for this well was changed from the early to the latter part of the fiscal year and, thus, the well was not sampled during calendar year 1999. One well near B Plant showed a uranium concentration of 17.8 μg/L in 1999. Wells adjacent to the inactive 216-B-62 crib showed a maximum concentration of 27.2 μg/L in 1999.

***Uranium in the 200-West Area***. The highest uranium concentrations in Hanford Site groundwater occurred near U Plant, at wells downgradient from the inactive 216-U-1 and 216-U-2 cribs and adjacent to the 216-U-17 crib (see Figure 6.1.19). The uranium plume, which extends into the 600 Area to the east, is approximately in the same location as the technetium-99 plume discussed above. Uranium and technetium-99 were typically associated with the same fuel reprocessing cycle and were disposed to the same cribs. However, uranium is less mobile than technetium-99 because of its stronger sorption to the sediment. A greater proportion of the uranium contamination remains at or near the source area. The high concentrations exceeded the

derived concentration guide for uranium. The maximum detected in this area in 1999 was 2,800 μg/L adjacent to the 216-U-17 crib, the same as in 1998.

As of September 1999, the 200-UP-1 pump-and-treat system removed a total of 101.1 kilograms (223 pounds) of uranium from approximately 357 million liters (99 million gallons) of extracted groundwater since operations began in 1994 (DOE/RL-99-79). The uranium plume at concentrations greater than the 480-mg/L cleanup level is contained and has slightly decreased in size since 1995. Uranium concentrations have increased in wells near the pump-and-treat injection well. These increases are attributed to rebound since injection well operations ceased in 1997.

Other areas with uranium contamination at levels above the proposed drinking water standard are also shown in Figure 6.1.19, including areas west and northwest of the Reduction-Oxidation Plant. Uranium concentrations in those areas are considerably lower than the concentrations detected near U Plant. The maximum uranium in these areas was 74.3 μg/L immediately east of tank farms S and SX (northwest of the Reduction-Oxidation Plant). In the northern part of the 200-West Area, a localized area of uranium contamination, where a single sample showed a concentration above the proposed drinking water standard at a level of 49.7 μg/L, was found near T Plant.

***Uranium in the 300 Area***. A plume of uranium contamination exists near uranium fuel fabrication facilities and inactive sites known to have received uranium waste. The plume extends downgradient from inactive liquid waste disposal facilities to the Columbia River (Figure 6.1.20). The major source of the contamination is the inactive 316-5 process trenches, as indicated by the distribution of the uranium concentrations downgradient from these trenches. The maximum concentration detected in 1999 was 322 μg/L near the Columbia River. Because wastewater is no longer discharged to the 316-5 process trenches, elevated concentrations at the south end of the process trenches indicate that the soil column contributes uranium contamination to the groundwater. Uranium levels in the 300 Area fluctuate annually but have shown an overall decline.

A localized area of elevated levels of uranium between the 324 Building and the Columbia River showed a maximum concentration of 163 μg/L in 1999 (see Figure 6.1.20).

***Uranium in the 600 Area***. A well southeast of the 400 Area (adjacent to Route 4S) had a maximum uranium concentration of 101 μg/L in 1999. Uranium levels have not changed significantly in this well in recent years. The contamination at this well is attributed to the nearby inactive 316-4 crib. The retired 618-10 burial ground is also located near this well.

**Strontium-90**. Strontium-90 was produced as a high-yield fission product and was present in waste streams associated with fuel reprocessing. Reactor operations also resulted in the release of some strontium-90 associated with fuel element breaches. Strontium-90 mobility in Hanford Site groundwater is reduced by adsorption onto sediment particles. However, strontium-90 is moderately mobile in groundwater because its adsorption is much weaker than for other radionuclides such as cesium-137 and plutonium. Because of sorption, a large proportion of the strontium-90 in the subsurface is not present in solution. The half-life of strontium-90 is 29.1 years.

In 1999, strontium-90 concentrations at greater than the 8-pCi/L interim drinking water standard were found in one or more wells in each of the 100, 200, and 600 Areas. Levels of strontium-90 were greater than the 1,000-pCi/L derived concentration guide in the 100 and 200 Areas. The 100-N Area had the widest distribution with the highest concentrations detected at the Hanford Site during 1999.

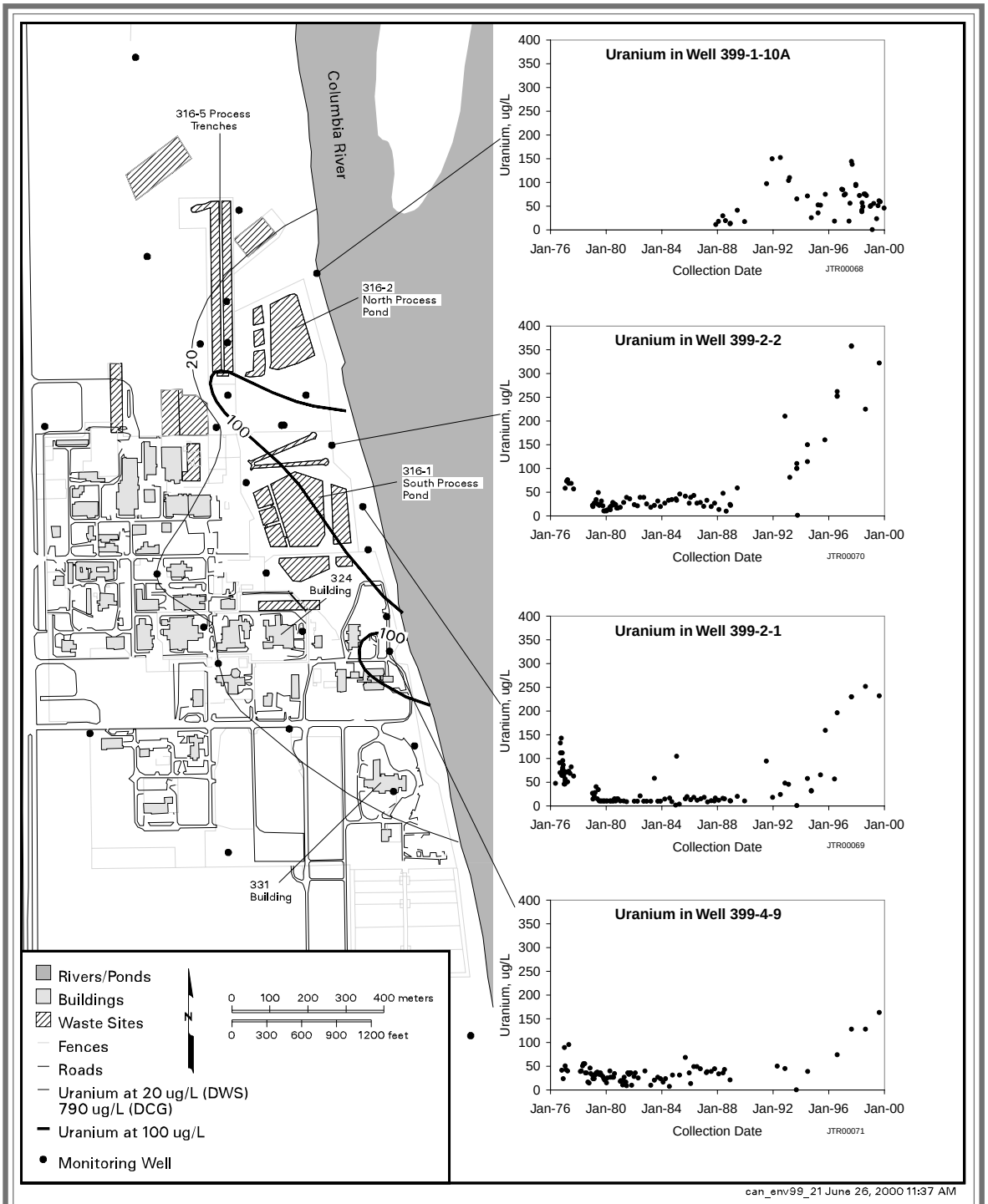


**Figure 6.1.20. Average Uranium Concentrations in the Unconfined Aquifer in the 300 Area, 1999, and Concentration Trends for Select Wells**

***Strontium-90 in the 100 Areas***. Strontium-90 concentrations greater than the interim drinking water standard extend from the B Reactor complex to the Columbia River in the northeastern part of the 100-B,C Area (Figure 6.1.21). The highest concentrations continued to be found in wells near the inactive 116-B-1 and 116-C-1 trenches and trends indicate concentration levels are not decreasing or increasing. The maximum concentration detected in 1999 was 70 pCi/L near the inactive 116-C-1 trench. The sources for the strontium-90 appear to be liquid waste disposal sites near B Reactor and liquid overflow trenches near the Columbia River (DOE/EIS-0119F).

Strontium-90 is not widely distributed in the 100-D Area. Strontium-90 levels are consistently greater than the interim drinking water standard in one well near the inactive D Reactor fuel storage basin. The maximum level was 30.6 pCi/L in 1999. Strontium-90 was detected at levels just above the interim drinking water standard near the former 116-D-7 retention basin in the northern part of the 100-D Area. Strontium-90 levels in the 100-D Area have not changed significantly in recent years.

Strontium-90 exceeded the interim drinking water standard near the 116-F-14 retention basins and 116-F-2 and 116-F-9 trenches in the eastern part of the 100-F Area. The maximum concentration detected in 1999 was 329 pCi/L. Strontium-90 levels fluctuate in the 100-F Area.

In the 100-H Area, strontium-90 contamination levels greater than the interim drinking water standard were present in an area adjacent to the Columbia River near the 107-H retention basin. The maximum detected in the 100-H Area in 1999 was 55.3 pCi/L between the retention basin and the Columbia River. Strontium-90 levels in the 100-H Area have not shown consistent trends between wells. The source of the contamination is past disposal of reactor coolant containing strontium-90 to retention basins and trenches in the 100-H Area. Contaminated soil was excavated from the upper portion of the vadose zone at these facilities and disposed of to the Environmental Restoration Disposal Facility during 1999.

Strontium-90 at levels greater than the interim drinking water standard continues to show up in isolated areas in the 100-K Area. These areas include fuel storage basin drain fields/injection wells associated with the KE and KW Reactors and between the 116-K-2 liquid waste disposal trench and the Columbia River. The maximum concentration detected in 1999 was 6,970 pCi/L at well 199-K-109A, the only well in the 100-K Area where levels were above the derived concentration guide. Concentrations show a variable trend in this well. The original source of the strontium-90 in this well was identified as past-practice disposal to the 116-KE-3 drain field/injection well near KE Reactor (PNNL-12023). Maximum strontium-90 concentrations near the KW Reactor and the disposal trench were 39.1 pCi/L and 47.6 pCi/L, respectively.

The distribution of strontium-90 in the 100-N Area is shown in Figure 6.1.22. Strontium-90 was detected at concentrations greater than the derived concentration guide in several wells located between the 1301-N Liquid Waste Disposal Facility, a source of the strontium-90, and the Columbia River. The 1325-N Liquid Waste Disposal Facility is also a source of strontium-90 in groundwater. The maximum level detected in 1999 was 22,000 pCi/L near the head end of the 1301-N facility (well 199-N-67). Strong, positive correlations between high groundwater-level elevations and high strontium-90 concentrations in wells indicate that strontium-90 is remobilized during periods of high water levels.

In the 100-N Area, strontium-90 discharges to the Columbia River through springs along the shoreline. Section 4.2, "Surface Water and Sediment Surveillance" and Section 3.2, "Near-Facility Environmental Monitoring," give the results of spring water sampling. Because of high concentrations in wells near the river, it was expected that strontium-90 exceeded the interim drinking water standard at

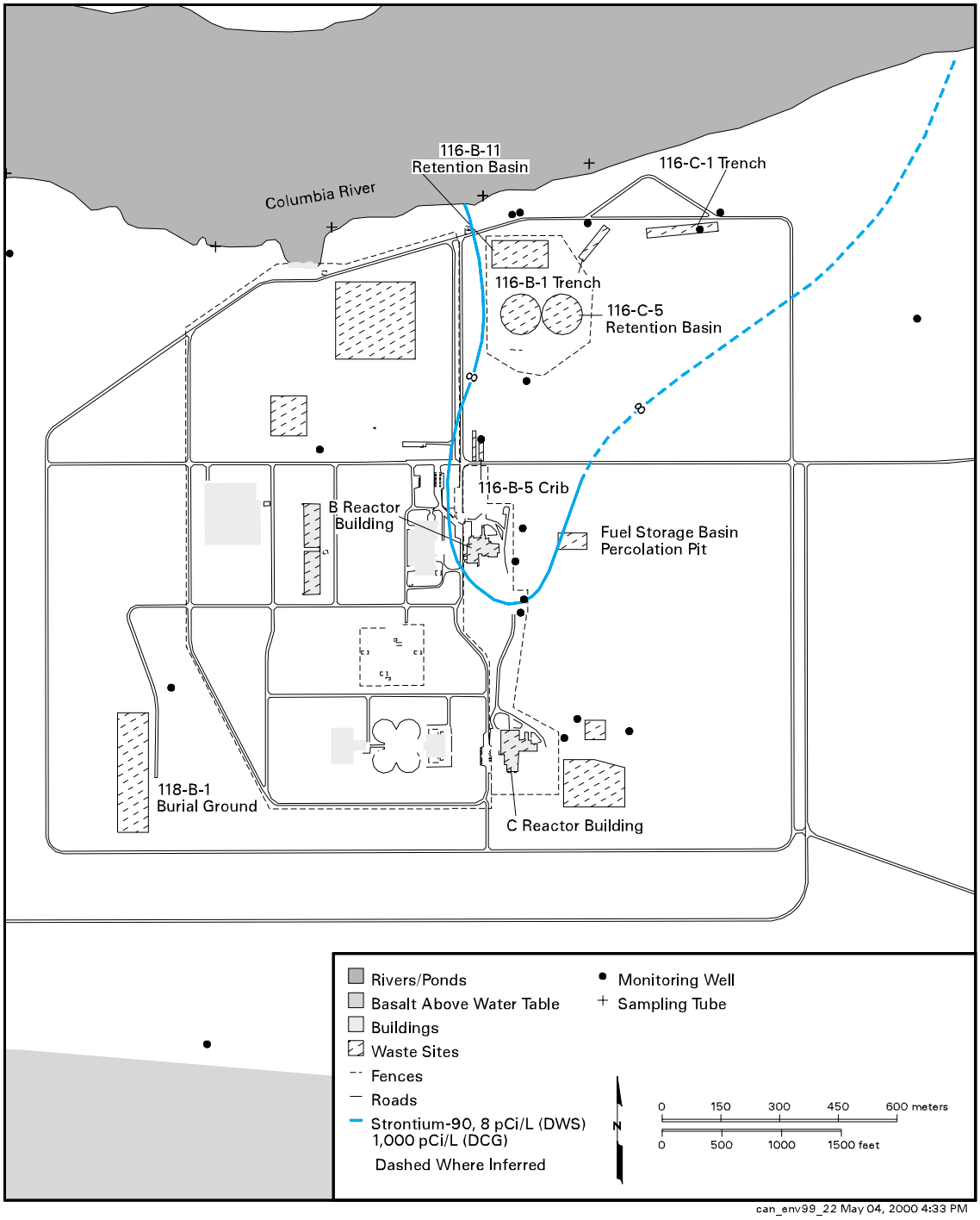


**Figure 6.1.21. Average Strontium-90 Concentrations in the Unconfined Aquifer in the 100-B,C Area, 1999**

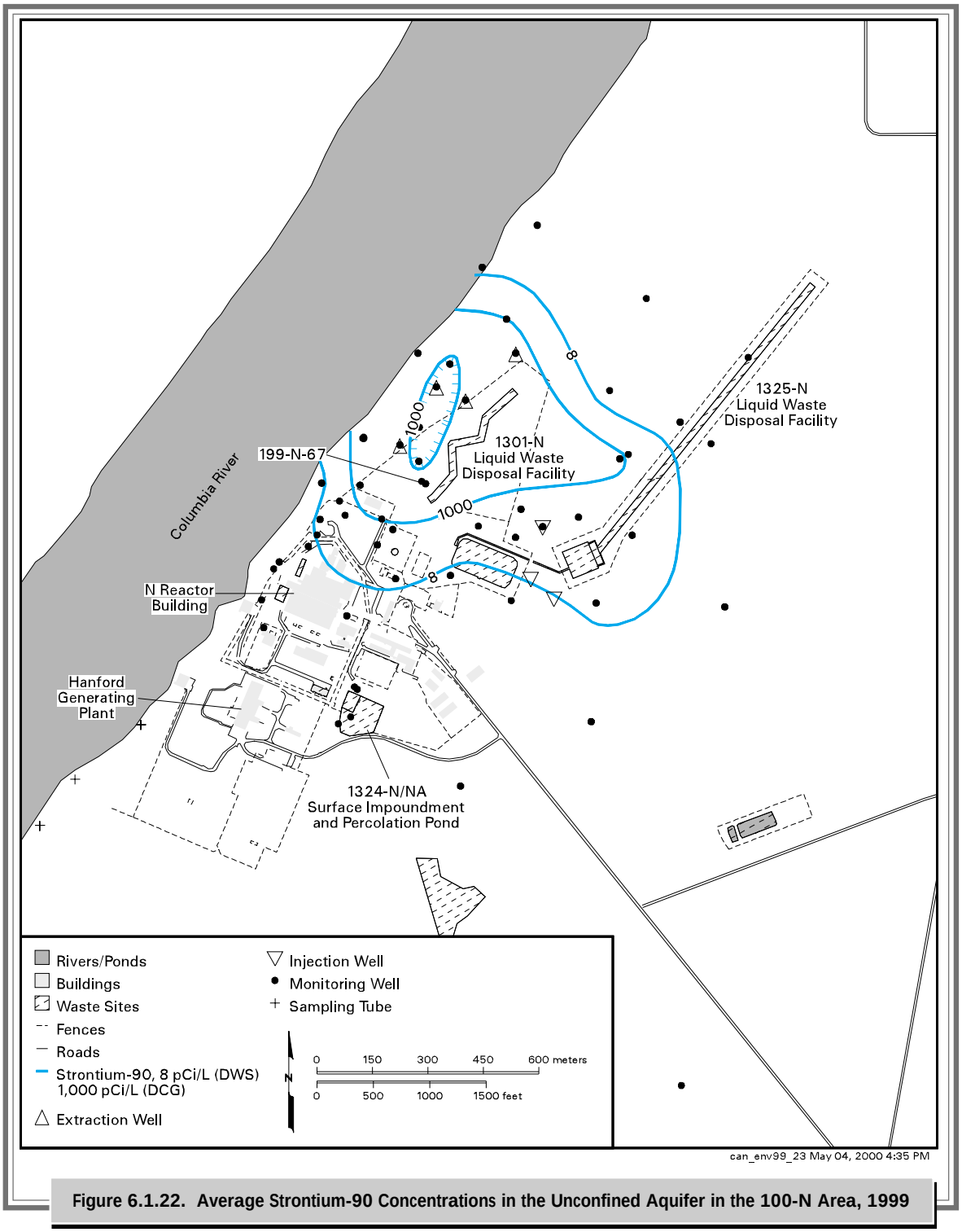


**Figure 6.1.22. Average Strontium-90 Concentrations in the Unconfined Aquifer in the 100-N Area, 1999**

the interface between the groundwater and the river (DOE/RL-96-102). The highest strontium-90 concentration in a near-river well in 1999 was 13,100 pCi/L. Groundwater contaminated with strontium-90 entering the river could potentially reach an aquatic and riparian ecological receptor through direct uptake. Ecological risks associated with groundwater discharge to the Columbia River have been quantified in PNNL-11933.

A pump-and-treat method began in 1995 to remove strontium-90 from groundwater in the 100-N Area. The objective is to reduce the amount of strontium-90 from entering the Columbia River. Pumping from the extraction wells create a hydraulic sink between the 1301-N facility and the river. This reduces or reverses the hydraulic gradient in the groundwater toward the river and results in less groundwater and strontium-90 discharging to the river. The pump-and-treat system, which uses ion-adsorption technology, removed ~0.2 curie of strontium-90 from extracted groundwater during fiscal year 1999 (DOE/RL-99-79). This is compared to an estimated total of 76 to 88 curies in the aquifer (in groundwater and adsorbed on the saturated sediments) (DOE/RL-95-110).

***Strontium-90 in the 200 Areas***. Strontium-90 distribution in the 200-East Area is shown in Figure 6.1.18. Strontium-90 concentrations in the 200-East Area were above the derived concentration guide in one well near the inactive 216-B-5 injection well. The maximum concentration was 1,900 pCi/L in well 299-E28-25. Well 299-E28-23 had a maximum concentration of 10,800 pCi/L in December 1998. This well is scheduled to be sampled again in fiscal year 2000. Strontium-90 levels have shown a steady increase in this well since 1990. The injection well received an estimated 27.9 curies of strontium-90 during 1945 and 1946 (PNL-6456). In the 200-East Area, strontium-90 was detected above the interim drinking water standard in one well near the Plutonium-Uranium Extraction Plant cribs. Strontium-90 levels have been stable in this well. Strontium-90 was not detected at levels above the interim drinking water standard in the 200-West Area in 1999.

***Strontium-90 in the 600 Area***. In the 600 Area, the highest strontium-90 concentrations were detected in wells in the former Gable Mountain Pond area (see Figure 6.1.18). In three of the wells, levels fell below the derived concentration guide in 1999 after increasing to peak levels above the guide in 1997 and 1998. The maximum strontium-90 concentration in this area in 1999 was 948 pCi/L. Strontium-90 contamination in this area resulted from the discharge of radioactive liquid waste to the former Gable Mountain Pond during its early use.

**Carbon-14**. Carbon-14 concentrations occur in the 100-K Area and exceed the 2,000-pCi/L interim drinking water standard in two small plumes near the KE and KW Reactors (Figure 6.1.23). The sources of the carbon-14 were the 116-KE-1 and 116-KW-1 cribs, respectively. Carbon-14 was included with tritium in the condensate wastewater disposed to the cribs. However, the distribution of carbon-14 in groundwater is not the same as for tritium because carbon-14 interacts with carbonate minerals and thus disperses more slowly than does tritium (PNNL-12023). The maximum concentration in 1999 was 35,600 pCi/L near the 116-KW-1 crib. Carbon-14 levels have remained stable in most of the 100-K Area wells. The derived concentration guide for carbon-14 is 70,000 pCi/L. Carbon-14 has a long half-life of 5,730 years, which suggests that some of the carbon-14 will reach the Columbia River before it decays.

**Cesium-137**. Cesium-137, which has a half-life of 30 years, is produced as a high-yield fission product and is present in waste streams associated with fuel processing. Former reactor operations also may have resulted in the release of some cesium-137 associated with fuel element breaches. Normally, cesium-137 is strongly sorbed on soil and, thus, is not very mobile in Hanford Site groundwater. The

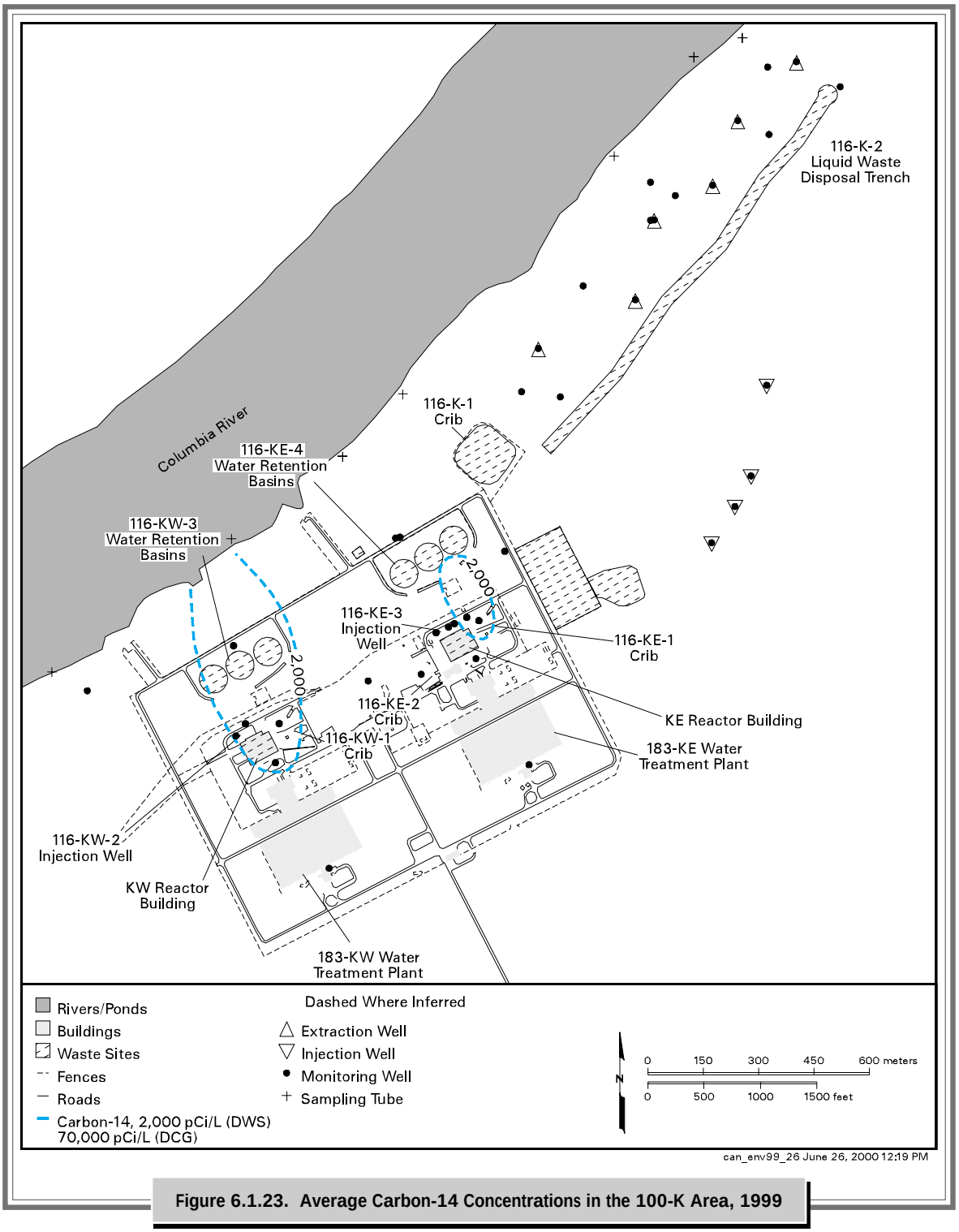


**Figure 6.1.23. Average Carbon-14 Concentrations in the 100-K Area, 1999**

interim drinking water standard for cesium-137 is 200 pCi/L; the derived concentration guide is 3,000 pCi/L.

Cesium-137 was detected in three wells located near the inactive 216-B-5 injection well in the 200-East Area. The injection well received waste containing cesium-137 from 1945 to 1947. Annual measurements of cesium-137 in one of these wells consistently show levels greater than the interim drinking water standard. Because the sampling schedule was changed from December to May of the fiscal year, a sample was not collected from this well during calendar year 1999. The fiscal year 1999 sample was collected in December 1998, and the fiscal year 2000 sample was collected in May 2000. Cesium-137 appears to be restricted to the immediate vicinity of the former injection well.

**Cobalt-60**. Cobalt-60 in groundwater is typically associated with waste generated by reactor effluent. Cobalt-60 is normally present as a divalent transition metal cation and, as such, tends to be immobile in groundwater. However, complexing agents may mobilize it. All cobalt-60 levels in groundwater samples analyzed in 1999 were below the 100-pCi/L interim drinking water standard. The derived concentration guide for cobalt-60 is 5,000 pCi/L.

Cobalt-60 concentrations were detected in the northwestern part of the 200-East Area and the adjacent 600 Area north of the 200-East Area. These are the same areas where the technetium-99 contamination associated with the BY cribs is found. Apparently, cobalt in this plume is mobilized by reaction with cyanide or ferrocyanide in the waste stream, forming a dissolved cobalt species. The maximum concentration measured in 1999 was 62.7 pCi/L at the BY cribs. Because of its relatively short half-life (5.3 years), much of the cobalt-60 in groundwater in this area has decayed to lower concentrations.

**Plutonium**. Plutonium was released to the soil column in several locations in both the 200-West and 200-East Areas. Plutonium is generally considered to sorb strongly to sediment, which limits its mobility in the aquifer. The derived concentration guide for both plutonium-239 and plutonium-240 is 30 pCi/L. Radiological analysis is incapable of distinguishing between plutonium-239 and plutonium-240; therefore, the results are expressed as a concentration of plutonium-239/240. There is no explicit drinking water standard for plutonium-239/240; however, the gross alpha drinking water standard of 15 pCi/L would be applicable at a minimum. Alternatively, if the derived concentration guide that is based on a 100-millirem dose standard is converted to the 4-millirem dose equivalent used for the drinking water standard, 1.2 pCi/L would be the relevant guideline. The half-lives of plutonium-239 and plutonium-240 are 24,000 and 6,500 years, respectively.

The only well where plutonium isotopes have been detected in groundwater above the 30-pCi/L derived concentration guide was near the inactive 216-B-5 injection well in the 200-East Area. Because the sampling schedule was changed from December to May of the fiscal year, a sample was not collected from this well during calendar year 1999. The fiscal year 1999 sample was collected in December 1998, and the fiscal year 2000 sample was collected in May 2000. Two other wells near the inactive injection well showed levels above the 1.2-pCi/L relevant drinking water guideline. The maximum concentration in 1999 was 3.9 pCi/L. Plutonium levels have not changed significantly in these three wells. Because plutonium is strongly adsorbed to sediment and may have been injected into the aquifer as suspended particles, it is likely that the values measured result in part from solid rather than dissolved material. The injection well received an estimated 244 curies of plutonium-239/240 during its operation from 1945 to 1947 (PNL-6456).

## 6.1.6.2 Chemical Monitoring Results for the Unconfined Aquifer

In recent years, chemical analyses performed by various monitoring programs at the Hanford Site have identified several hazardous chemicals in groundwater at concentrations greater than their respective drinking water standards. Nitrate, chromium, and carbon tetrachloride are the most widely distributed of these hazardous chemicals and have the highest concentrations in groundwater at the Hanford Site. Hazardous chemicals that are less widely distributed and have lower concentrations in groundwater include chloroform, trichloroethylene, tetrachloroethylene, cis-1,2-dichloroethylene, cyanide, and fluoride.

A number of parameters such as pH, specific conductance, total carbon, total organic carbon, and total organic halides are used as indicators of contamination. These are mainly discussed in Section 6.1.7, "RCRA Summary." Other chemical parameters listed in Table 6.1.4 are indicators of the natural chemical composition of groundwater and are usually not considered contaminants from operations at the Hanford Site. These include alkalinity, aluminum, calcium, iron, magnesium, manganese, potassium, silica, and sodium. Chloride and sulfate occur naturally in groundwater and can also be introduced as contaminants from site operations. There is no primary drinking water standard for chloride or sulfate. The secondary standard for each is 250 mg/L and is based on aesthetic rather than health considerations; therefore, they will not be discussed in detail. The analytical technique used to determine the concentration of metals in groundwater provides results for a number of constituents. These trace metal constituents, rarely observed at greater than background concentrations, include antimony, barium, beryllium, boron, cadmium, copper, nickel, silver, vanadium, and zinc.

The following presents a summary of the chemical constituents in groundwater at concentrations greater than existing or proposed drinking water standards (40 CFR 141 and EPA 822-R-96-001; see Appendix C).

**Nitrate**. Many groundwater samples collected in 1999 were analyzed for nitrate. Nitrate was measured at concentrations greater than the drinking water standard (45 mg/L as nitrate ion) in wells in all operational areas. Nitrate is associated primarily with process condensate liquid wastes, though other liquids discharged to the ground also contained nitrate. Nitrate contamination in the unconfined aquifer reflects the extensive use of nitric acid in decontamination and chemical reprocessing operations. However, additional sources of nitrate, primarily associated with agriculture, occur off the site to the south, west, and southwest. The distribution of nitrate on the Hanford Site is shown in Figure 6.1.24; this distribution is similar to previous evaluations. Although nitrate contamination can be detected over large areas of the site, the areas impacted by levels greater than the drinking water standard are small. Nitrate at levels above the drinking water standard occurs in the 100, 200, and 600 Areas.

***Nitrate in the 100 Areas***. Nitrate concentrations have generally been rising in many 100 Area wells. However, there is no current explanation for the rises. A plume containing slightly elevated levels of nitrate occurs in the northeastern part of the 100-B,C Area. In 1999, the maximum nitrate concentration in this area was 50 mg/L, which exceeded the drinking water standard.

Nitrate is found at levels greater than the drinking water standard in much of the 100-D Area. The highest nitrate level found in the 100-D Area in 1999 was 100 mg/L in the southwestern part of the area and near the 120-D-1 ponds. Nitrate concentrations are not changing significantly in the 100-D Area except near the 120-D-1 ponds, where levels show increasing trends.

Nitrate continues to be widely distributed in 100-F Area groundwater. The central and southern

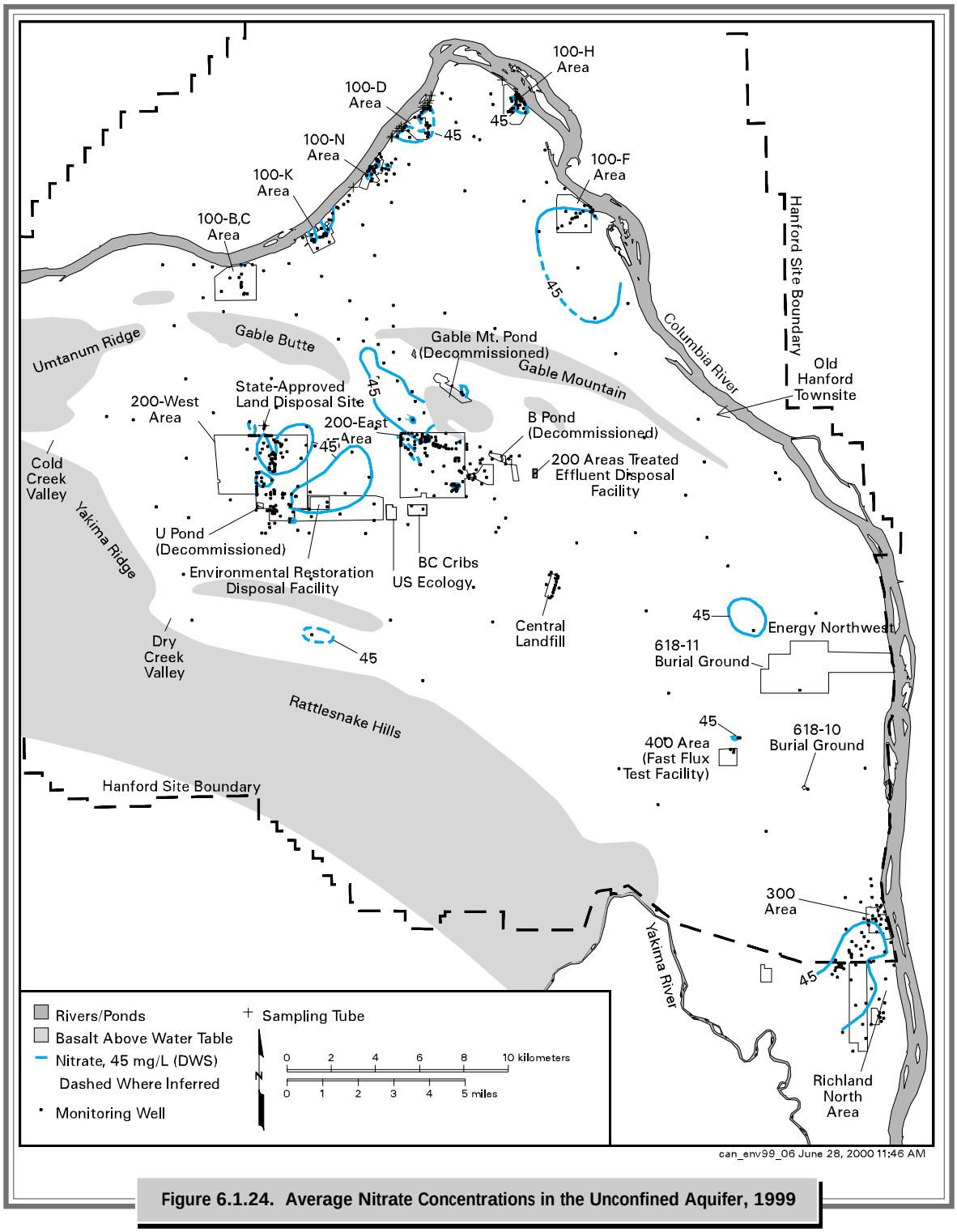


**Figure 6.1.24. Average Nitrate Concentrations in the Unconfined Aquifer, 1999**

portions of the 100-F Area contain nitrate at levels greater than the drinking water standard. Trends show increasing nitrate levels in these areas. This plume extends to the south and southeast into the 600 Area from upgradient sources near F Reactor. In the southern part of the 100-F Area, groundwater flow was to the southeast. The maximum nitrate detected in the 100-F Area in 1999 was 144 mg/L in the southwestern part of the 100-F Area.

A nitrate plume with concentrations above the drinking water standard lies in the eastern portion of the 100-H Area adjacent to the Columbia River. The highest concentrations are restricted to a small area downgradient of the former 183-H solar evaporation basins. The concentrations fluctuate in this small area and have been some of the highest on the site. The maximum nitrate detected in 1999 was 387 mg/L near the basins.

Nitrate at levels greater than the drinking water standard in the 100-K Area are found downgradient of both the KE and KW Reactors and appear to reach the Columbia River. The maximum concentration detected in 1999 was 155 mg/L in a well adjacent to the KE Reactor.

Although detected over most of the 100-N Area, nitrate contamination above the drinking water standard occurs at isolated locations in the 100-N Area. The maximum was 150 mg/L in a well located between the 1301-N Liquid Waste Disposal Facility and the Columbia River.

***Nitrate in the 200-East Area***. The nitrate plume in the 200-East Area covers a nearly identical area to that of the tritium plume. However, the area with nitrate exceeding the drinking water standard is smaller than the area with tritium exceeding its drinking water standard. Nitrate exceeds the drinking water standard in the northern part of the 200-East Area and adjacent 600 Area to the northwest and near the Plutonium-Uranium Extraction Plant in the southeastern part of the 200-East Area. In the northern part of the 200-East Area, the plume has two parts, a western plume that extends from B Plant to the northwest and an eastern portion that extends from the BY cribs to the northwest. The two portions of the plume join northwest of the 200-East Area. A 1999 nitrate plume map of the 200-East and adjacent 600 Areas is presented in Figure 2.9-5 of PNNL-13116.

In 1999, the highest 200-East Area concentrations were reported in several wells near the 216-B-8 crib. The maximum concentration was 536 mg/L in a well adjacent to the inactive 216-B-8 crib. Nitrate levels continue to increase near the 216-B-8 and BY cribs. High nitrate concentrations in the 600 Area north of the 200-East Area are apparently related to past disposal practices at the BY cribs.

High nitrate concentrations continued to be found near liquid waste disposal facilities that received effluent from Plutonium-Uranium Extraction Plant operations. Nitrate concentrations in wells near the inactive 216-A-10 and 216-A-36B cribs have tended to decrease in the past few years but remained greater than the drinking water standard, although these cribs were removed from service in 1987. The maximum nitrate concentration detected in this vicinity was 133 mg/L adjacent to the 216-A-36B crib.

Nitrate is also elevated in a few wells near the former Gable Mountain Pond north of the 200-East Area. In 1999, the highest measured concentration in this area was 402 mg/L.

***Nitrate in the 200-West Area***. Nitrate concentrations greater than the drinking water standard were widespread in groundwater beneath the 200-West Area and adjacent parts of the 600 Area. The major nitrate plumes were found in wells east of U Plant and wells in the north-central part of the 200-West Area. The widespread distribution of nitrate reflects the multiple sources in the 200-West Area. Nitrate plume maps of the 200-West and adjacent 600 Areas are presented in Figures 2.8-10 and 2.8-31 of PNNL-13116.

Some of the highest nitrate concentrations across the site continued to be found in wells southeast of U Plant, where the maximum detected in 1998 was 1,673 mg/L in a well adjacent to the inactive 216-U-17 crib. Nitrate concentrations were not monitored in wells near this crib in 1999 because nitrate is not used to indicate performance of this pump-and-treat system. The presence of nitrate in wells near this crib was detected before February 1988 when the crib went into operation. The source of nitrate is believed to be waste disposed in the 216-U-1 and 216-U-2 cribs southwest of U Plant. These cribs received more than 1,000,000 kilograms (2,200,000 pounds) of chemicals containing nitrate during their operation from 1951 to 1967 (PNL-6456). As of September 1999, the pump-and-treat system near the 216-U-17 crib has removed 12,770 kilograms (28,153 pounds) of nitrate from ~357 million liters (99 million gallons) of extracted groundwater (DOE/RL-99-79). Nitrate has been removed from extracted groundwater since March 1997. However, nitrate is not the primary target of the pump-and-treat system.

Nitrate concentrations (maximum of 63 mg/L) continued to be elevated above the drinking water standard near other inactive cribs to the south that are associated with the U Plant and Reduction-Oxidation Plant. These elevated levels represent nitrate plumes that coalesce with the plume from the U Plant area. A small, isolated plume of elevated nitrate occurs west of the Reduction-Oxidation Plant near the inactive 216-S-25 crib and S and SX tank farms, where the maximum concentration was 562 mg/L. Nitrate concentrations in this small plume have increased or remained stable.

A large area, encompassing the northern half of the 200-West Area, contains nitrate in groundwater at concentrations much greater than the drinking water standard. Wells showing the highest concentrations are located near several inactive liquid waste disposal facilities that received waste from early T Plant operations. A large amount of nitrate was disposed to these cribs (e.g., ~2,300,000 kilograms [5,100,000 pounds] of nitrate to the 216-T-7 crib). Maximum concentrations in these wells in 1999 ranged up to 1,049 mg/L west of T Plant near the inactive T, TX, and TY tank farms. Nitrate concentrations have increased or remained stable near these tank farms. High, stable concentrations of nitrate (251 mg/L) were also found in 1999 at the northeastern boundary of the 200-West Area.

A smaller area of elevated nitrate concentrations above the drinking water standard is located in vicinity of the Plutonium Finishing Plant, which is in the central part of the 200-West Area. The highest reported concentration was 440 mg/L near the Plutonium Finishing Plant in 1999. Nitrate concentrations have been stable in this area.

***Nitrate in Other Areas***. Nitrate contamination occurs near the city of Richland in the former 1100 Area, Richland North Area, and adjacent parts of the 600 Area along the southern boundary of the Hanford Site. This contamination is apparently affected by nitrate sources off the site. These sources may include agriculture, food processing, and nuclear fuel manufacturing at offsite commercial facilities. The part of this plume with nitrate concentrations greater than the drinking water standard extends from off the site, south of the former Horn Rapids Landfill, to the 300 Area to the northeast. The area of the nitrate plume at levels greater than the drinking water standard continued to expand in the southern part of the Hanford Site in 1999. The maximum nitrate concentration in 1999 was 168 mg/L on the northeastern edge of the Horn Rapids Landfill. Large increases in nitrate levels occurred off the Hanford Site ~1,200 meters (4,000 feet) northwest of the city of Richland's north well field and recharge ponds in 1999. Nitrate concentrations changed from 48 mg/L in 1998 to 124 mg/L in 1999 at one well showing the largest increase. The most likely source of the increased levels is agricultural practices to the west. A 1999 plume map showing detail of the nitrate distribution is presented in Figure 2.12-10 in PNNL-13116.

Although most nitrate observed on the site is the result of Hanford Site operations, elevated nitrate concentrations in the western part of the site appear to be the result of increasing agricultural activity in offsite areas (e.g., Cold Creek Valley). There is no known source of nitrate in these areas associated with site operations, and groundwater flow is from the west toward the Hanford Site facilities to the east. Nitrate levels have fluctuated considerably in wells upgradient of the 200 Areas over the past 30 years. In Cold Creek Valley, nitrate levels have been near or greater than the drinking water standard in one well since 1985. A maximum nitrate concentration of 54 mg/L, the same as in 1998, was found in a well located just north of the Rattlesnake Hills.

Nitrate was detected at levels exceeding the drinking water standard in a well downgradient of the 400 Area process ponds. These levels, which have remained steady, were attributed to a former sanitary sewage lagoon west of the process ponds. The maximum concentration observed was 92 mg/L in 1999.

**Chromium**. Use of chromium on the Hanford Site has been extensive. In the 100 Areas, sodium dichromate was added to cooling water as a corrosion inhibitor, and some residual chromium remains from that use. Chromium was used for decontamination in the 100, 200, and 300 Areas and also was used for oxidation state control in the Reduction-Oxidation Plant process. In the hexavalent form, chromium is present in an anionic state. Thus, hexavalent chromium is freely mobile in the groundwater. The drinking water standard for chromium is 100 μg/L.

Both filtered and unfiltered samples were collected from several of the wells onsite for analyses of chromium and other metals. Unfiltered samples may contain metals present as particulate matter, whereas filtered samples are representative of the more mobile, dissolved metals. Filtered samples also may contain some colloidal particles that are fine enough to pass through the filter. Drinking water standards are based on unfiltered concentrations. However, differences in well construction and pumping practices between monitoring wells and water supply wells make it difficult to predict potential drinking water concentrations from monitoring well data when the metals are present as particulate matter. In general, filtered samples provide the best indication of groundwater contamination levels for chromium because unfiltered samples are subject to greater variability introduced by the sampling process. Chromium concentrations in filtered samples, which are considered representative of dissolved hexavalent chromium, will be used to describe the level of contamination in the discussion below.

***Chromium in the 100 Areas***. Chromium has been detected above the drinking water standard in the 100-B,C, 100-D, 100-H, 100-K, and 100-N Areas. Groundwater pump-and-treat systems continued to operate in 1999 to reduce the amount of hexavalent chromium entering the Columbia River at the 100-D, 100-H, and 100-K Areas. The purpose of the pump-and-treat systems is to prevent discharge of hexavalent chromium into the Columbia River at concentrations exceeding 11 μg/L, which is the EPA's standard for protection of freshwater aquatic life.

Chromium exceeded the drinking water standard from filtered samples in the 100-B,C Area in 1999. The maximum concentration was 111 μg/L downgradient of former water treatment facilities, where sodium dichromate may have leaked from storage tanks and transfer facilities. Chromium concentrations have shown a general rise in the last few years, but with annual variability.

The chromium distribution in the 100-D Area is shown in Figure 6.1.25. Chromium contamination at levels greater than the drinking water standard is defined by two plumes. The plume boundaries and concentrations in the southwestern portion of the 100-D Area were defined with better confidence in 1999 than in 1998 because twelve new monitoring

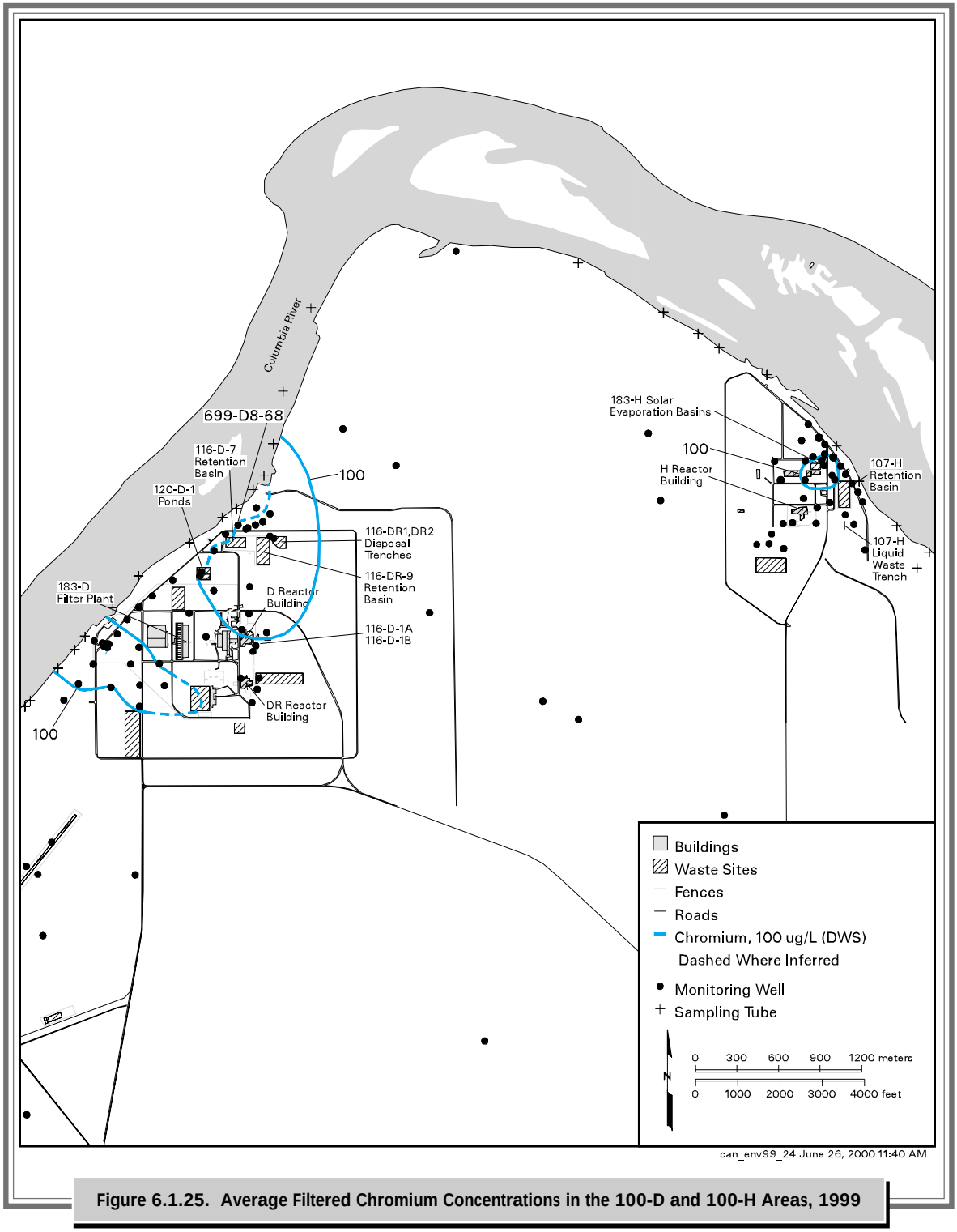


**Figure 6.1.25. Average Filtered Chromium Concentrations in the 100-D and 100-H Areas, 1999**

wells drilled in 1999 were available for sampling. In 1999, the maximum chromium concentration from filtered samples was 2,210 μg/L in the southwestern portion of the 100-D Area. The source of this plume is suspected to be sodium dichromate used in the 190-DR building or disposed of in nearby waste sites. The source of the chromium plume in the northern part of the 100-D Area is sodium dichromate released to the ground at former facilities near D Reactor. Leakage from inactive retention basins and liquid waste disposal trenches north of D Reactor may also have contributed to the chromium plume. The maximum chromium concentration in the northern plume was 898 μg/L.

In situ redox manipulation technology is currently being demonstrated in the southwestern 100-D Area to address hexavalent chromium contamination in groundwater. This technology immobilizes hexavalent chromium by reducing the soluble chromate ion to highly insoluble chromium hydroxide or iron chromium hydroxide. In 1999, results of a treatability study indicated that hexavalent chromium concentrations continue to be less than the detection limit (7 μg/L) within the treatment zone and have declined in downgradient wells.

Many samples from 100-H Area wells contained chromium at levels greater than the drinking water standard (see Figure 6.1.25). In 1999, the maximum chromium concentration from filtered samples collected from the shallow parts of the unconfined aquifer was 204 μg/L in a well near the former 183-H solar evaporation basins. Chromium levels have fluctuated in response to changing water-table conditions. Potential sources include past disposal of sodium dichromate near H Reactor, disposal to the inactive 107-H liquid waste disposal trench, and chromium in acid wastes stored in the former 183-H basins (Peterson and Connelly 1992). Upgradient sources include waste sites in the 100-D Area. Chromium was also found at levels above the drinking water standard in one well monitoring the deeper part of the unconfined aquifer. Filtered samples from this well, located near the former 183-H basins, contained 182 μg/L of chromium in 1999. Chromium levels in this well have been decreasing in recent years.

A groundwater remediation pump-and-treat system to decrease the amount of hexavalent chromium entering the Columbia River from the aquifer continued to operate in the 100-D and 100-H Areas in 1999. Groundwater extracted from the 100-D Area wells downgradient of the inactive retention basins is piped to the 100-H Area for treatment. Groundwater extracted from the 100-D and 100-H Area wells is treated using ion-exchange technology and then reinjected into the aquifer in the southwestern part of the 100-H Area. Performance of the interim action to pump and treat has shown that hydraulic containment, resulting from the operation of the extraction wells, reduced the amount of chromium entering the river from the aquifer in both the 100-D and 100-H Areas. By the end of September 1999, ~66 kilograms (146 pounds) of chromium were removed from groundwater extracted from these areas since pump-and-treat operations began in July 1997. Chromium concentrations have decreased in some extraction wells and monitoring wells, but the rate of decline is not consistent throughout the targeted plume area.

Chromium in the 100-K Area occurs in groundwater near or at levels greater than the drinking water standard in three areas (Figure 6.1.26). Two localized areas of chromium contamination occur near the KW Reactor and the water treatment basins southeast of the KE Reactor. The maximum concentration in 1999 was 606 μg/L near the KW Reactor. Trends show that chromium concentrations are increasing near the KW Reactor. Chromium concentrations reached a maximum of 161 μg/L in well 199-K-36 adjacent to the 183-KE water treatment basins and inactive sodium dichromate storage tanks. This concentration is a decrease from 249 μg/L in 1998. A much wider area of chromium contamination is found in vicinity of the former 116-K-2 liquid waste disposal trench to the northeast. The maximum concentration in this area

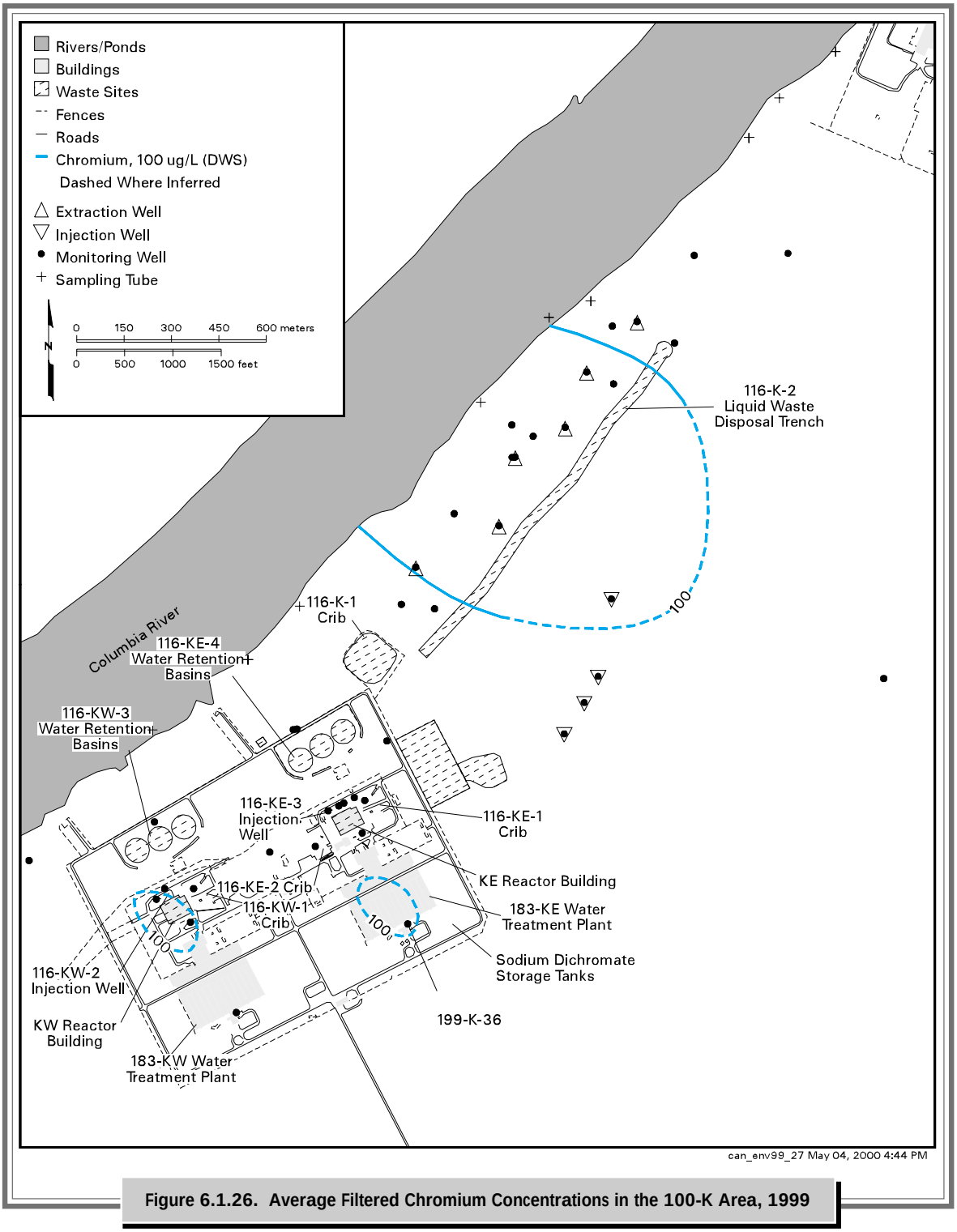


**Figure 6.1.26. Average Filtered Chromium Concentrations in the 100-K Area, 1999**

was 194 μg/L in 1999. A pump-and-treat system for treating chromium in groundwater between the trench and the Columbia River, which began operating in October 1997, continued to operate in 1999. Groundwater extracted from a network of wells is treated using ion-exchange technology and then returned to the aquifer upgradient of the 116-K-2 trench. By the end of September 1999, ~70 kilograms (154 pounds) of chromium had been removed from extracted groundwater. Hexavalent chromium concentrations have shown a slight downward trend in several of the extraction wells, but have not fallen below the target concentration of 22 μg/L.

In the 100-N Area, chromium contamination is not widespread in groundwater. However, filtered samples in one well that monitors a locally confined unit within the Ringold Formation have consistently shown concentrations at steady levels greater than the drinking water standard northwest of the 1301-N Liquid Waste Disposal Facility. The maximum chromium concentration in 1999 was 176 μg/L. The source for the contamination at this location is unknown. Chromium was disposed to the 1301-N Liquid Waste Disposal Facility until the early 1970s (DOE/RL-96-39).

***Chromium in the 200 Areas***. Chromium at concentrations greater than the drinking water standard in the 200-East Area was found in two wells on the southern boundary of A and AX tank farms. The maximum concentration detected in the sample was 1,420 μg/L. Concentrations in this well have been variable, and the source of the chromium is unknown.

Chromium contamination has been found at several locations in the 200-West Area. Areas where concentrations exceeded the drinking water standard in 1999 include the T, TX, and TY tank farms and 216-S-10 pond. Filtered samples from a well monitoring the TX and TY tank farms showed a maximum concentration of 433 μg/L, the highest filtered chromium concentration in the 200-West Area. The highest concentration found in the vicinity of the T tank farm was 192 μg/L. Chromium concentrations have generally been increasing at these locations. The highest concentration near the former 216-S-10 pond was 213 μg/L. Chromium concentrations near this former pond have generally been decreasing after rising to a peak concentration of 576 μg/L in 1997.

***Chromium in Other Areas***. Filtered chromium concentrations above the drinking water standard have been known to occur downgradient of the 200-West Area (located southwest of the 200-East Area). However, the sampling frequency of wells in this area was changed from annual to every 3 years in 1998 because historical trends showed that chromium concentrations were steady in these wells. The maximum concentration in this area in 1997 was 226 μg/L. The extent of chromium contamination in this area is poorly defined, and the source has not been determined.

**Carbon Tetrachloride**. Carbon tetrachloride contamination occurs above the 5-μg/L drinking water standard in much of the 200-West Area and represents one of the most significant contaminant plumes at the Hanford Site (Figure 6.1.27). The plume, which covers an area that is more than 11 square kilometers (4 square miles), extends past the 200-West Area boundary into the 600 Area. However, the overall carbon tetrachloride distribution has changed little since the plume was first identified in 1987.

The bulk of the contamination is believed to be from waste disposal operations associated with the Plutonium Finishing Plant in the west-central part of the 200-West Area. Major sources identified in this area include the 216-Z-9 trench, the 216-Z-1A drain/tile field, and the 216-Z-18 crib. Carbon tetrachloride was used as the carrier solvent for tributyl phosphate in the final purification of plutonium. Carbon tetrachloride was also used in the same facility as a nonflammable thinning agent while machining plutonium. A minor source of carbon

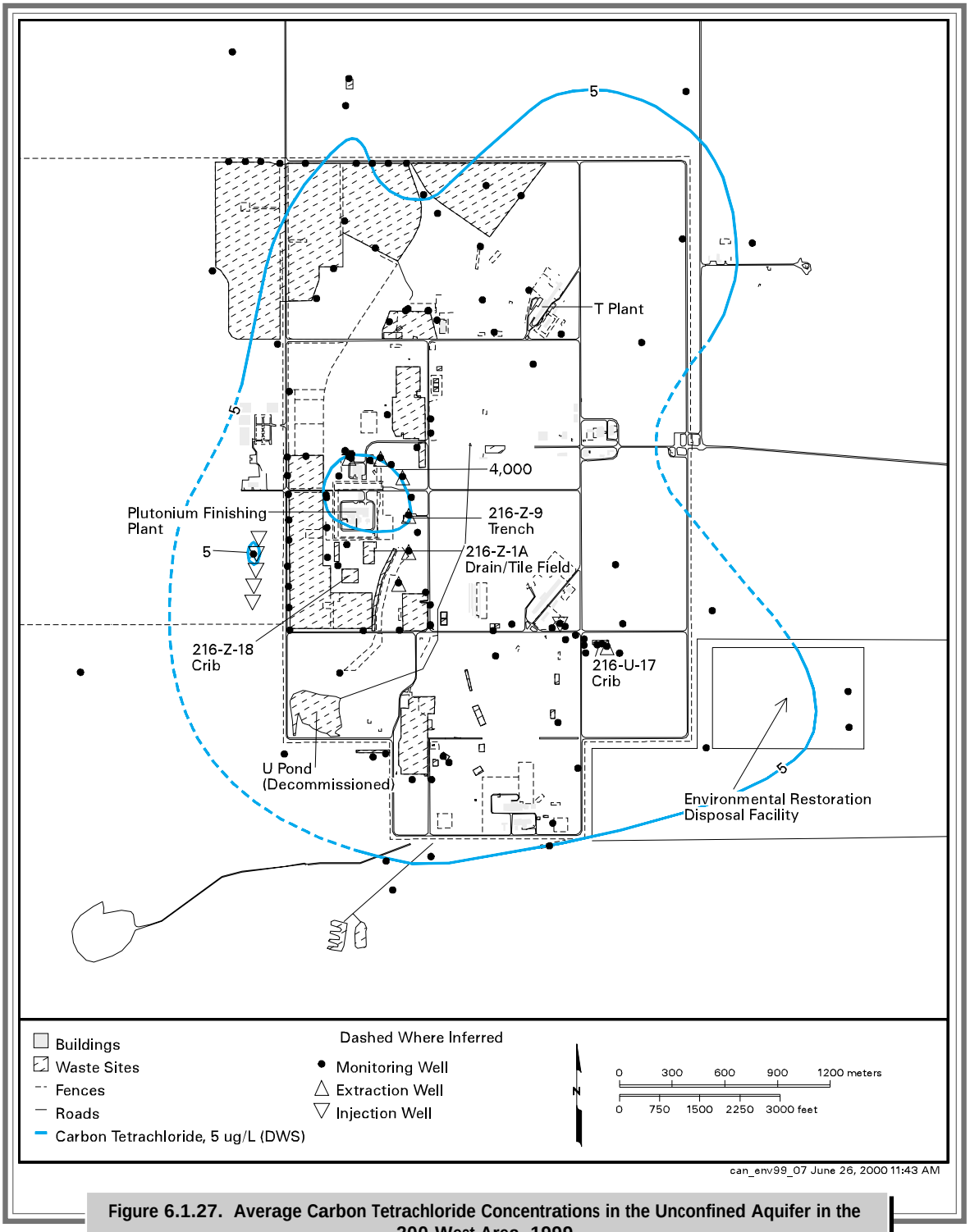


**Figure 6.1.27. Average Carbon Tetrachloride Concentrations in the Unconfined Aquifer in the 200-West Area, 1999**

tetrachloride is a former waste disposal crib near T Plant. Carbon tetrachloride is immiscible in water but exhibits a relatively high solubility (805,000 µg/L at 20° Celsius [68° Fahrenheit]). Carbon tetrachloride has been found to have a relatively high degree of mobility in groundwater. Mobilization above the water table can also occur through vapor transport.

Wells in vicinity of the Plutonium Finishing Plant showed the highest concentrations in the plume, with levels exceeding the drinking water standard by more than two orders of magnitude. The maximum concentration was 7,900 µg/L near one pump-and-treat extraction well just northeast of the plant. Pump-and-treat operations, which began in 1994, have influenced the distribution of carbon tetrachloride. The area within the 4,000-µg/L contour has increased in size because of the effects of pumping from the extraction wells downgradient of this area. The plume center continues to move in a northerly and easterly direction toward the extraction wells, as evidenced by increased concentrations in several extraction and monitoring wells (BHI-01311, Rev. 0). The extraction wells are located north and east of the Plutonium Finishing Plant. Carbon tetrachloride concentrations in vicinity of the injection wells southwest of the plant continue to decline as a result of injection of the treated water. As of September 1999, ~955 million liters (252 million gallons) of extracted groundwater have been treated, resulting in the removal of 3,386 kilograms (7,465 pounds) of carbon tetrachloride (DOE/RL-99-79).

Near the 216-U-17 crib in the southeastern part of the 200-West Area, the pump-and-treat system removed 15.8 kilograms (34.8 pounds) of carbon tetrachloride from ~357 million liters (99 million gallons) of extracted groundwater. This amount has been removed as of September 1999 (DOE/RL-99-79).

The extent of carbon tetrachloride contamination in deeper parts of the aquifer is uncertain because of the limited concentration data from depths below the water table. The limited amount of data indicates that the concentrations are highest at the top of the aquifer and decline with depth at most locations within the plume. A detailed summary of available data indicates that carbon tetrachloride concentrations range up to 3,789 µg/L in the middle part of the unconfined aquifer (BHI-01311, Rev. 0). In the lower part of the unconfined aquifer, carbon tetrachloride concentrations range up to 2,651 µg/L. These data represent samples collected between 1991 and 1999.

Changes in groundwater flow since decommissioning U Pond may influence the plume configuration and the concentrations at particular locations. Another potential influence is the continued spreading of carbon tetrachloride above the water table, in either the liquid or the vapor phase. Free-phase, liquid, carbon tetrachloride above and possibly below the water table provides a continuing source of contamination. Therefore, lateral expansion of the carbon tetrachloride plume is expected to continue.

**Chloroform**. A chloroform plume appears to be associated with, but not exactly coincident with, the carbon tetrachloride plume in the 200-West Area (Figure 6.1.28). The highest chloroform concentrations were measured in vicinity of the Plutonium Finishing Plant, where the maximum level was 140 µg/L. This is a slight increase from 1998 chloroform levels. The drinking water standard for chloroform is 100 µg/L (total trihalomethanes), which is 20 times higher than that for carbon tetrachloride. The origin of chloroform is suspected to be a degradation product of carbon tetrachloride or an anaerobic degradation product associated with septic drain fields.

**Trichloroethylene**. A commonly used organic solvent, trichloroethylene has a drinking water standard of 5 µg/L. In 1999, trichloroethylene was detected at levels greater than the drinking water standard in some wells in the 100, 200, 300, and

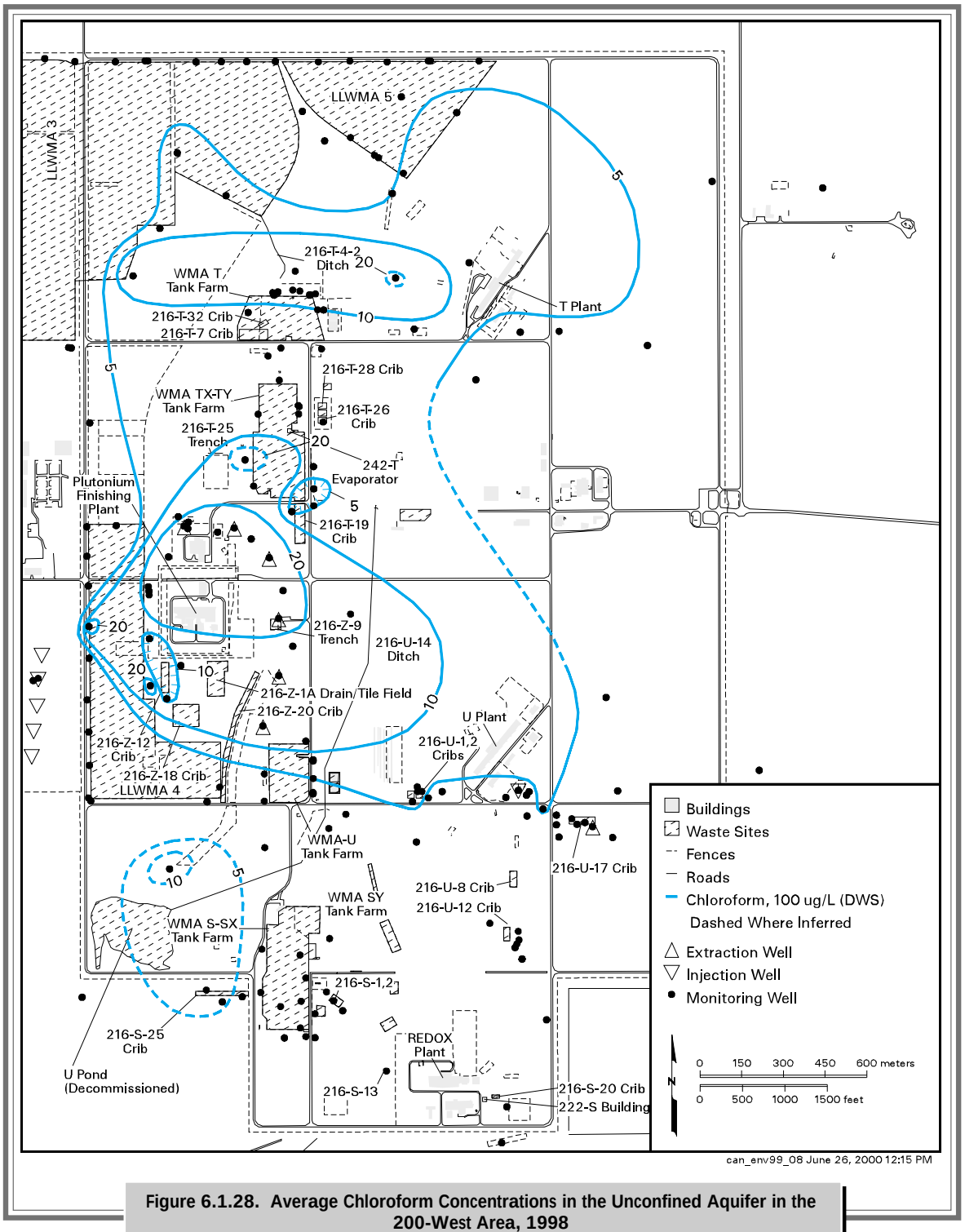


**Figure 6.1.28. Average Chloroform Concentrations in the Unconfined Aquifer in the 200-West Area, 1998**

600 Areas. The most widespread area of contamination occurred in the 200-West Area.

***Trichloroethylene in the 100 Areas***. Trichloroethylene was detected at levels greater than the drinking water standard in the southwestern corner of the 100-F Area and in the adjacent 600 Area. Trichloroethylene concentrations in this area show declining trends. The maximum concentration detected in this area was 18 μg/L in the adjacent 600 Area. No specific sources of this contamination have been identified.

In the 100-K Area, two wells sampled contained trichloroethylene at levels above the drinking water standard, representing a localized area of contamination near the KW Reactor complex. This area of contamination resulted from the past disposal/spillage of organic solvents. The maximum concentration was 23 μg/L in monitoring well 199-K-106A. Trichloroethylene concentrations appear to be decreasing with time.

***Trichloroethylene in the 200 Areas***. Trichloroethylene was detected at levels greater than the drinking water standard in several parts of the 200-West Area (Figure 6.1.29). The most significant area extends from the Plutonium Finishing Plant northeast to the northern boundary of the 200-West Area. The source of the contamination is presumably past disposal in these plant areas. The highest concentration was 33 μg/L northeast of the Plutonium Finishing Plant. A smaller, isolated area of contamination occurs downgradient of the U Plant cribs, where the maximum concentration was 15 μg/L. Trichloroethylene concentrations in the 200-West Area did not change significantly between 1998 and 1999.

***Trichloroethylene in the 300 Area***. Trichloroethylene was detected at one well in 1999 in the 300 Area at concentrations above the drinking water standard. The maximum concentration was 6 μg/L at well 399-1-16B. This well monitors the base of the unconfined aquifer downgradient of the former 316-5 process trenches. Trichloroethylene concentrations in the 300 Area have been declining.

***Trichloroethylene in the 600 Area***. Trichloroethylene was found at levels above the drinking water standard in two wells in vicinity of the former Horn Rapids Landfill in the southern part of the site (Richland North Area). This contamination, which is degrading naturally, forms an elongated plume that extends from an area just south of the landfill to near the southwestern corner of the 300 Area and has an origin off the Hanford Site (Figure 6.1.30). Since 1990, trichloroethylene concentrations have decreased from levels exceeding 100 μg/L. The maximum concentration detected in this plume in 1999 was 6 μg/L on the northeastern side of the landfill.

**cis-1,2-Dichloroethylene**. Concentrations of cis-1,2-dichloroethylene, a biodegradation product of trichloroethylene, remain elevated in well 399-1-16B, located near the former process trenches and ponds in the 300 Area. This well is completed in the deeper part of the unconfined aquifer and is the only well on the site where this constituent is found at levels above the 70-μg/L drinking water standard. In 1999, a maximum of 180 μg/L, the same as in 1998, was detected in this well.

**Cyanide**. Waste fractionation activities performed in the late 1950s used large quantities of sodium and nickel ferrocyanide to recover cesium-137. Large volumes of aqueous supernatant waste containing excess ferrocyanide were disposed to the ground in both the northern and southern portions of the 200-East Area. Smaller quantities were also disposed to former cribs in the 200-West Area. Procedures used to analyze for cyanide do not distinguish between ferrocyanide and free cyanide. Cyanide results reported here are, thus, normally assumed to be residual ferrocyanide associated with the discharges from the waste fractionation activities performed more than 30 years ago. A chemical speciation study performed in 1988 indicated that

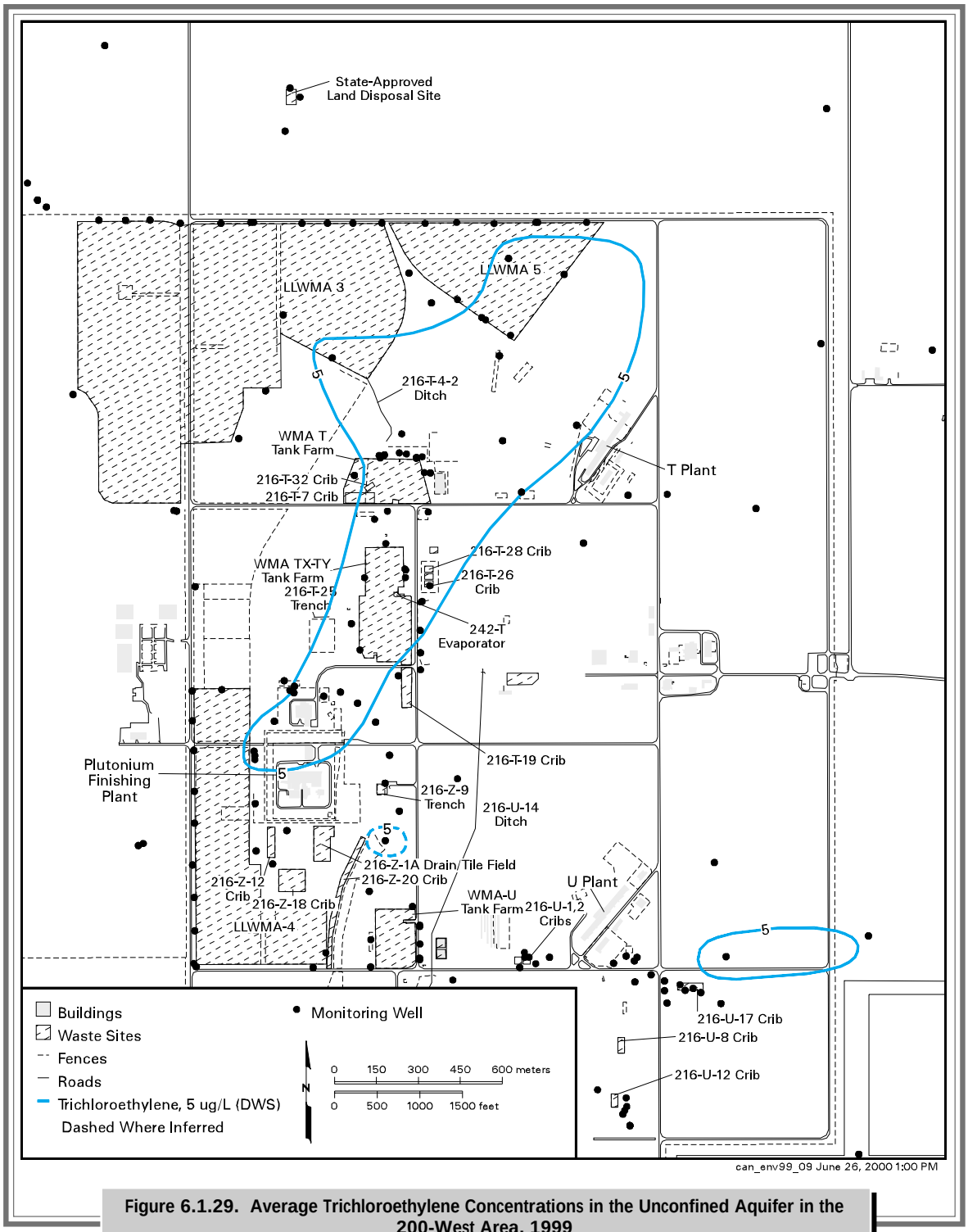


**Figure 6.1.29. Average Trichloroethylene Concentrations in the Unconfined Aquifer in the 200-West Area, 1999**

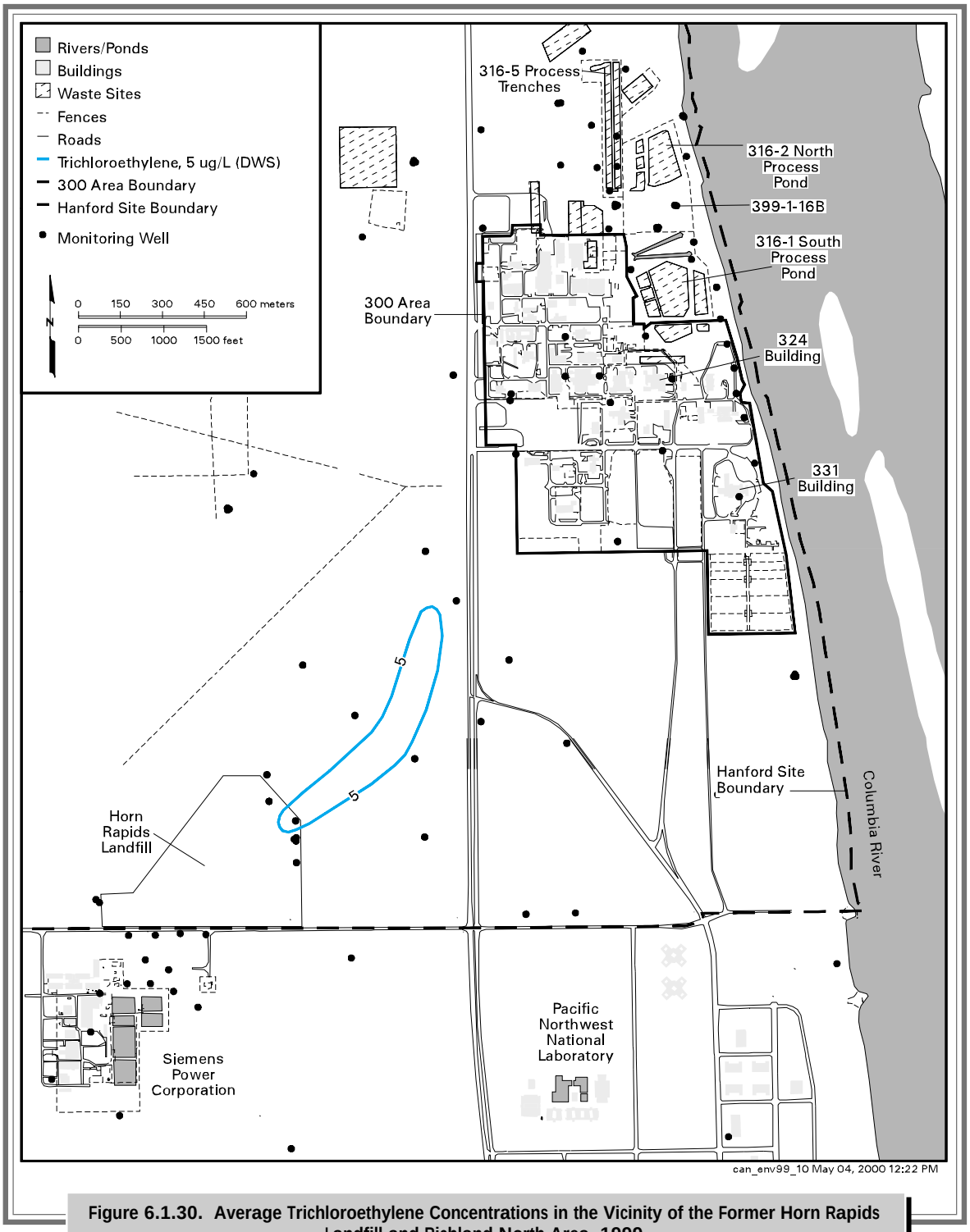


**Figure 6.1.30. Average Trichloroethylene Concentrations in the Vicinity of the Former Horn Rapids Landfill and Richland North Area, 1999**

approximately one-third of the cyanide in groundwater is present as free cyanide and the rest may be present as ferrocyanide (Section 4.1 in PNL-6886 and Section 3.2.2 in PNL-7120). The drinking water standard for cyanide is 200 µg/L.

The highest cyanide levels were detected in samples collected from wells in the northwestern part of the 200-East Area and in the 600 Area north of the 200-East Area. Samples collected from two wells near the inactive BY cribs showed concentrations above the drinking water standard in 1999. Cyanide levels are increasing near the BY cribs. The maximum concentration of 289 µg/L correlates with cobalt-60 levels. Wells containing cyanide often contain several radionuclides, including cobalt-60. Although cobalt-60 is normally immobile in the subsurface, it appears to be chemically complexed by cyanide or ferrocyanide. The complexed chemical species is more soluble and more mobile in groundwater.

**Fluoride**. At this time, fluoride has a primary drinking water standard of 4 mg/L and a secondary standard of 2 mg/L. Secondary standards are based primarily on aesthetic rather than health considerations. Fluoride was detected above the primary drinking water standard near T tank farm in the 200-West Area in 1999. Fluoride levels near T tank farm increased slightly between 1998 and 1999. The maximum fluoride concentration was 5.3 mg/L. A few wells near the T tank farm showed concentrations above the secondary standard. Aluminum fluoride nitrate used in past 200-West Area processes is the probable source of the fluoride contamination.

## 6.1.6.3 Radiological and Chemical Monitoring Results for the Basalt-Confined Aquifer

Aquifers confined below the uppermost basalt layers show much less impact from Hanford Site contamination than the unconfined aquifer system within the overlying sediment. The minor contamination found in the basalt-confined aquifers may be attributed to several factors. These factors include areas where the confining layers of basalt have been eroded away, areas where disposal of large amounts of water resulted in downward gradients, and areas where wells penetrating to the confined aquifers provided pathways for contaminant migration. These factors produced intercommunication between the aquifers, meaning they permitted the flow of groundwater from the unconfined aquifer to the underlying confined aquifer, thereby increasing the potential to spread contamination.

Intercommunication between the unconfined and basalt-confined aquifers in vicinity of the northern part of the 200-East Area has been identified previously in RHO-BWI-ST-5 and RHO-RE-ST-12 P. The hydrochemical and hydrogeologic conditions within the upper basalt-confined aquifer system and the potential for offsite migration of contaminants through confined aquifer pathways were evaluated in PNL-10817.

Several confined aquifer wells north and east of the 200-East Area that show evidence of intercommunication with the overlying unconfined aquifer were identified in PNL-10817. Intercommunication between the unconfined and confined aquifers in this area has been attributed to erosion of the upper Saddle Mountains Basalt and downward vertical gradients that result from groundwater mounding associated with waste disposal. Groundwater chemical data from most confined aquifer wells in other areas of the Hanford Site do not exhibit evidence of contamination. Exceptions are wells that were previously open to both the unconfined and confined aquifers, thus providing conduits for the downward transport of contamination.

Approximately 10 years of groundwater sample data for the basalt-confined aquifer indicate that very few areas of concern were warranted for annual sampling. Consequently, the number of wells sampled annually has progressively been reduced since 1995.

The schedule for most of the basalt-confined aquifer wells has been reduced to a triennial sampling frequency. Well 699-42-E9B was the only basalt-confined aquifer well sampled in 1999. Sample results from this well, located east of the Columbia River, showed essentially no contamination. The distribution of contaminants in the basalt-confined aquifer is shown in previous annual reports (e.g., Figure 6.1.35 in PNNL-12088). The locations of wells used for monitoring confined aquifer groundwater chemistry were given in Figure 6.1.9.

## 6.1.7 RCRA Summary

More than 60 treatment, storage, and disposal units are recognized under the RCRA permit for the Hanford Site. Of these, 26 required groundwater monitoring during 1999. Locations of these groundwater monitoring sites were given in Figure 6.1.10. This section provides a summary of groundwater monitoring activities and results for these sites. Additional information, including RCRA groundwater monitoring and complete listings of radioactive and chemical constituents measured in monitoring wells from October 1998 through September 1999, is available in PNNL-13116. Any significant changes that occurred from October through December 1999 are noted below.

RCRA groundwater monitoring is conducted under one of three phases: 1) indicator parameter/detection, 2) groundwater quality assessment/compliance, or 3) corrective action. Initially, a detection program is developed to monitor the impact of facility operations on groundwater. During the indicator parameter/detection phase, groundwater parameters established for the particular site are measured in wells upgradient and downgradient from the site. Statistical tests are applied to the monitoring results to calculate "critical mean" values for each monitoring parameter. These values represent the background water quality for the site. Subsequent monitoring data are compared to the critical mean values to determine if there has been a statistically significant change in the concentrations of key indicator parameters or dangerous waste constituents in the groundwater. The statistical methods used to calculate critical means and compare with monitoring data are described in Appendix B in PNNL-12086. If a statistically significant change from the "critical mean" is observed, then a groundwater quality assessment/compliance phase of monitoring and investigation is initiated. During this phase, groundwater monitoring is designed to determine if groundwater protection standards have been exceeded. If the source of the contaminants is determined to be the treatment, storage, and disposal unit and concentrations exceed maximum contaminant levels defined in the monitoring plan or permit, then the Washington State Department of Ecology may require corrective action to reduce the contaminant hazards to the public and environment. Groundwater monitoring during the corrective action phase is designed to assess the effectiveness of the corrective action. Table 2.2.2 in Section 2.2, "Compliance Status," lists the phase pertaining to each of the RCRA groundwater monitoring projects at the end of 1999.

### 6.1.7.1 100 Areas Facilities

**120-D-1 Ponds**. These ponds were constructed in 1977 for disposal of nonradioactive effluent derived from operating facilities in the 100-D,DR Area. This disposal facility is located in the former 188-D ash disposal basin and includes settling and percolation ponds separated by a dike. Effluent to the ponds originated from two sources: the 183-D filter plant and the 189-D building engineering testing laboratories. Some past discharges contained hydrochloric acid, sodium hydroxide, and sulfuric acid. Before 1986, the effluent may have had a pH greater than 12.5 or less than 2.0 and, thus, may

have been dangerous waste. There was also a potential for up to 2.3 kilograms (5 pounds) of mercury to have been discharged to the ponds. Between 1986 and 1994, the effluent discharged to the ponds included chlorine and flocculating (clumping) agents such as aluminum sulfate. Effluent discharge to the ponds ceased in 1994. Contaminated soils were removed from the ponds in 1996.

The 120-D-1 ponds well network was sampled once in 1999. After that, the Washington State Department of Ecology implemented modification E of the Hanford Site RCRA Permit (Ecology 1994) and the site was clean closed. This means that all dangerous waste or dangerous waste constituents or residues associated with the operation of the ponds have been removed. The closure plan (DOE/RL-92-71, Rev. 2) is a demonstration of clean closure, and there are no requirements for a landfill cover, postclosure care, or further groundwater monitoring. Statistical evaluations of indicator parameter data indicated that the ponds had no adverse impact on groundwater quality. Mercury is the only listed waste that may have been discharged to these ponds and was never detected in any of the downgradient monitoring wells. Chromium and nitrate from upgradient sources exceeded maximum contaminant levels.

**183-H Solar Evaporation Basins**. This facility consisted of four separate concrete basins surrounded by an earthen berm. The basins have been demolished and contaminated soil removed from the site. Between 1973 and 1985, the basins were used to store liquid waste, primarily from nuclear fuel fabrication activities conducted in the 300 Area. Solar evaporation reduced the volume of liquid waste. The waste was predominantly acid etch solution that had been neutralized with sodium hydroxide before being discharged into the basins. The solution included chromic, hydrofluoric, nitric, and sulfuric acids and also contained various metallic and radioactive constituents. Groundwater in the vicinity of these basins is characterized by elevated levels of chromium, nitrate, technetium-99, and uranium. All of these constituents were present in waste discharged to the basins when they were in use.

This site continued to be monitored under a final status corrective-action program during 1999 (WAC 173-303-645). The site was incorporated into the Hanford Site RCRA Permit (Ecology 1994) in 1998. Groundwater remediation is integrated with the 100-HR-3 operable unit, where remediation for chromium is under way. While the pump-and-treat system is operating, RCRA monitoring consists of annual sampling of four wells for chromium, fluoride, nitrate, technetium-99, and uranium (PNNL-11573). The wells were sampled in November 1999. Contaminant concentrations fluctuate in response to changes in river stage, and continued to exceed concentration limits in one or more wells.

**1301-N and 1325-N Liquid Waste Disposal Facilities**. These facilities contaminated groundwater with radionuclides, most notably strontium-90 and tritium, as discussed in Section 6.1.6.1, "Radiological Monitoring Results for the Unconfined Aquifer." A pump-and-treat system is active as a CERCLA interim action to reduce the amount of strontium-90 flowing into the Columbia River at the 100-N Area. RCRA monitoring focuses on the hazardous (nonradioactive) constituents discharged to the facilities.

The 1301-N facility was the primary liquid waste disposal site for N Reactor from 1963 until 1985. Discharges were primarily radioactive fission and activation products. Minor amounts of dangerous waste and other constituents may also have been discharged, including ammonium hydroxide, cadmium, diethylthiourea, lead, morpholine, phosphoric acid, and sodium dichromate. The facility consists of a concrete basin with an unlined, zigzagging extension trench, covered with concrete panels.

The 1325-N facility was constructed in 1983 and also received effluent from N Reactor. In 1985, discharge to 1301-N ceased, and all effluent was sent to 1325-N. All discharge to 1325-N ceased in late

1991. The facility consists of a concrete basin with an unlined extension trench, covered with concrete panels.

During 1999, upgradient and downgradient wells at the 1301-N and 1325-N facilities were sampled twice. The critical mean values for indicator parameters (pH, specific conductance, total organic carbon, and total organic halides) were revised in December 1999 to evaluate the data from September 1999 and from fiscal year 2000. The new values are based on recent data (1997 through 1999) from the upgradient wells. At the 1301-N facility, total organic carbon in downgradient well 199-N-3 exceeded the critical mean value in January, March, and September 1999. The Washington State Department of Ecology was notified in February 1999. Because no organic constituents of concern have been identified in 1301-N waste or sediment, the contamination is assumed to come from another source, and the site remains in indicator evaluation status.

The revised critical mean value for specific conductance at the 1325-N facility was lower than the previous value, and two of the downgradient wells exceeded the revised mean in September 1999. DOE notified the Washington State Department of Ecology and submitted an assessment report that concluded the exceedance did not indicate contamination from the facility (see Section 2.4 of PNNL-13116). Of the dangerous waste constituents or byproduct discharged to these facilities, only nitrate exceeded the maximum contaminant level, and the sources are unclear (see Section 2.4.3 of PNNL-13116). The 1301-N and 1325-N facilities have contaminated the groundwater with tritium and strontium-90, but radionuclides are not monitored as part of the RCRA program at these facilities.

The closure plan for these facilities was revised and incorporated into a modification of the Hanford Site RCRA Permit (Ecology 1994) in 1999. Remedial actions will be integrated with the 100-NR-1 and 100-NR-2 operable units. The closure plan (DOE/RL-96-39) states that RCRA monitoring during and after closure activities will continue, according to the existing interim status monitoring plan (WHC-SD-EN-AP-038, Rev. 2).

**1324-N and 1324-NA Ponds**. The 1324-N pond was a treatment facility that was in service from May 1986 to November 1988. This facility is a double-lined pond that was used for neutralizing high- and low-pH waste from a demineralization plant. The 1324-NA pond is unlined and was used for treating waste from August 1977 to May 1986 and for disposing of treated waste from May 1986 to August 1990. The effluent to both facilities contained sulfuric acid and sodium hydroxide, and the pH was occasionally high or low enough to classify the effluent as a dangerous waste.

Specific conductance in wells 199-N-59, 199-N-72, and 199-N-73 downgradient of the 1324-N/NA site continued to exceed the critical mean value in 1999. A previous groundwater quality assessment indicated that the high specific conductance is caused by the nonhazardous constituents sulfate and sodium (WHC-SD-EN-EV-003, Rev. 1). Because an assessment has been completed already and nonhazardous constituents caused the high conductance, no further action was needed.

Concentrations of total organic carbon in downgradient well 199-N-59 continued to exceed the critical mean value in March 1999. The Washington State Department of Ecology agreed that the contamination is from another source, so assessment monitoring is not required. Total organic carbon data from September 1999 did not exceed the revised critical mean value.

The closure plan for this facility was revised and incorporated into a modification of the Hanford Site RCRA Permit (Ecology 1994) in 1999. Remedial action will be integrated with the 100-NR-1 and 100-NR-2 operable units. The closure plan (DOE/RL-96-39) states that RCRA monitoring during and

after closure activities will continue, according to the existing interim status monitoring plan (WHC-SD-EN-AP-038, Rev. 2).

## 6.1.7.2 200 Areas Single-Shell Tank Farms

Single-shell tanks are located in the A, AX, B, BX, BY, C, S, SX, T, TX, TY, and U tank farms, which have been designated as parts of RCRA Waste Management Areas A-AX, B-BX-BY, C, S-SX, T, TX-TY, and U, respectively. Waste Management Areas A-AX, B-BX-BY, and C are located in the 200-East Area; Waste Management Areas S-SX, T, TX-TY, and U are in the 200-West Area. Each waste management area includes tanks and associated ancillary systems (e.g., pipelines). The single-shell tanks store a mixture of dangerous chemical and radioactive wastes generated by reprocessing fuel irradiated in Hanford Site reactors. The single-shell tanks received mixtures of organic and inorganic liquids that contain radionuclides, solvents, and metals that were originally discharged to the tanks as alkaline slurries. Subsequent waste management operations combined waste streams from different processes. In many tanks, wastes have been concentrated by removing water through evaporation.

**Waste Management Area A-AX**. This RCRA site continued to be monitored under an interim status indicator evaluation program in 1999. Wells were sampled twice for indicator and site-specific parameters. Indicator parameter data from upgradient wells were statistically evaluated, and values from downgradient wells were compared to those established from the upgradient wells. The indicator parameters (specific conductance, total organic carbon, pH, and total organic halides) did not exceed critical mean values during 1999.

Because of uncertainty in flow directions, the well network for this site may not be adequate for RCRA monitoring. The aquifer is less than 5 meters (16 feet) thick in RCRA network wells and the water table is declining. Three of the RCRA compliant wells at Waste Management Area A-AX may become unusable in 6 years.

**Waste Management Area B-BX-BY**. RCRA assessment monitoring continued at this waste management area in 1999. Exceedances of the critical mean value for specific conductance in February 1996 at well 299-E33-32 initiated assessment monitoring. An assessment monitoring plan (WHC-SD-ENV-AP-002, Rev. 0) was issued in September 1996, followed by an assessment investigation. Results indicated that tank waste from this waste management area had reached the groundwater (PNNL-11826). The assessment program is continuing to investigate the rate of movement and extent of groundwater contamination at this site (see Section 2.9.1 in PNNL-13116). Wells are monitored at least quarterly, and in some cases, monthly. In 1999, iodine-129, nitrate, technetium-99, and uranium exceeded maximum contaminant levels or drinking water standards in RCRA compliant wells, with corresponding exceedances of gross beta and gross alpha standards. Monitoring data from 1999 were used to define three distinct areas of contamination near the waste management area.

Originally, the RCRA groundwater monitoring network was designed for groundwater flow toward the northwest, based on regional plume maps. This method was used to determine flow direction because the water table is almost flat in the immediate area of the farms. As part of the ongoing studies, a series of steps are being taken to refine water-level measurements to allow a better determination of the approximate flow direction based on the local gradient.

**Waste Management Area C**. This RCRA site continued to be monitored under an interim status indicator evaluation program in 1999. Monthly sampling began in fiscal year 1999 to assess the potential impact of waste removal and sluicing of tank contents. In addition, the required detection sampling was conducted twice for indicator and

site-specific parameters. Indicator parameter data from upgradient wells were statistically evaluated. Values from downgradient wells were compared to values established from the upgradient wells. The indicator parameters (specific conductance, total organic carbon, pH, and total organic halides) did not exceed critical mean values during 1999.

Currently, the well network for this site appears to comply only marginally with the required placement of groundwater monitoring wells because of changes and uncertainty in the direction of flow.

**Waste Management Area S-SX**. This RCRA site continued to be monitored under an interim status assessment program during 1999. DOE initiated the assessment program in response to a directive from the Washington State Department of Ecology in 1996. The directive cited anomalous trends in technetium-99 and high specific conductance as primary reasons for the assessment. An assessment plan was submitted in August 1996 (WHC-SD-EN-AP-191). A report on the results of the assessment (PNNL-11810) concluded that this waste management area contributed to groundwater contamination. Accordingly, investigation of the rate and extent of the contamination is required. In 1999, contaminant concentrations fluctuated because of changing flow directions.

Three new wells were installed in 1999 and six more are planned in 2000 to improve spatial coverage and to replace wells going dry.

**Waste Management Area T**. This RCRA site continued to be monitored under an interim status assessment program during 1999. Waste Management Areas T and TX-TY began assessment monitoring in November 1992 because of high specific conductance in downgradient wells (WHC-SD-EN-AP-132, Rev. 0). Assessment findings (PNNL-11809) indicated that contaminants in well 299-W10-15 are a result of sources outside the waste management area. There is strong evidence, however, that contaminants observed in well 299-W11-27, which include chromium, cobalt-60, nitrate, technetium-99, and tritium, are a result of sources within the waste management area, so assessment work has continued. The plume detected in well 299-W11-27 has reached well 299-W11-23, located to the east of 299-W11-27, apparently as a result of changed groundwater flow direction at Waste Management Area T.

The current network of wells is inadequate for assessment monitoring. Four new wells are planned to be installed in 2000 to improve the monitoring coverage.

**Waste Management Area TX-TY**. This RCRA unit continued to be monitored under an interim status assessment program during 1999. Waste Management Area TX-TY began assessment monitoring in November 1991 because of high specific conductance in wells 299-W10-17 and 299-W14-12 (WHC-SD-EN-AP-132, Rev. 0). The exceedance in well 299-W14-12 was accompanied by elevated cobalt-60, iodine-129, technetium-99, and tritium. Assessment results (PNNL-11809) indicated that contaminants in well 299-W10-17 are a result of sources outside the waste management area. Assessment results for well 299-W14-12 indicate that the contamination is consistent with a source within the waste management area, though upgradient sources are also possible. Because there was no direct evidence for upgradient sources, assessment continues at the site. Well 299-W15-40 was drilled near the 216-T-25 trench in 1999 to evaluate its potential role in providing the observed contamination. Results indicate that the trench is not the source of contamination. In 1999, contaminant concentrations increased in many wells, apparently as a result of changing flow directions.

The well network is inadequate for assessment monitoring. The average distance between monitoring wells along the southeastern margin of the waste management area is ~70 meters (230 feet), and a plume could pass through undetected. In addition, because well 299-W14-12 is expected to go dry, there are no wells located at intermediate or farther distances to track plume movement, and there are no

upgradient wells for the northern portion of the waste management area (TY tank farm). Five new wells are planned to be installed in 2000.

**Waste Management Area U**. Monitoring for this waste management area was elevated from indicator evaluation to assessment in 1999. Critical mean values of the indicator parameters (pH, specific conductance, total organic carbon, and total organic halides) were revised in December 1999 based on recent upgradient data. The revised values were applied to data from August 1999. Recent specific conductance values in the upgradient wells have been lower and have had less variability than in the past, so the revised critical mean value is lower. Consequently, downgradient well 299-W19-41 exceeded the revised critical mean in August 1999. DOE submitted an assessment plan to the Washington State Department of Ecology in March 2000 (PNNL-13185).

Two downgradient wells (299-W18-30 and 299-W19-42) continued to exceed the critical mean value of total organic halides during the first quarter of 1999. The exceedance is caused by an upgradient source of carbon tetrachloride, and a letter of notification and assessment report were submitted to the Washington State Department of Ecology in August 1998. Field specific conductance in two new downgradient wells (299-W19-41 and 299-W19-42) exceeded the critical mean value in February 1999. However, those values were erroneous. Anomalous, high field measurements were attributed to a bad batch of calibration solution and the problem was corrected. The critical range for pH was exceeded in one downgradient well (299-W19-12) during February 1999. This well was a pre-RCRA well that has had higher pH historically.

## 6.1.7.3 200 Areas Liquid Effluent Disposal Facilities

**216-A-10, 216-A-36B, and 216-A-37-1 Cribs**. These inactive cribs in the 200-East Area received liquid waste from the Plutonium-Uranium Extraction Plant and contributed to the widespread plumes of tritium, iodine-129, and nitrate described in Sections 6.1.6.1 and 6.1.6.2. The waste stream at the 216-A-10 crib was characteristically acidic and contained concentrated salts, hydrocarbon compounds, organic complexants, plutonium, uranium, and other radionuclides. The 216-A-36B crib received ammonia scrubber distillate from nuclear fuel decladding operations, in which zirconium cladding was removed from irradiated fuel by boiling in a solution of ammonium fluoride and ammonium nitrate. Other waste stream constituents included tritium, cobalt-60, strontium-90, ruthenium-106, iodine-129, cesium-137, and uranium. The 216-A-37-1 crib received process condensate from the 242-A evaporator. The process condensate contained radionuclides, spent halogenated and nonhalogenated solvents, and ammonia. The radionuclides included cobalt-60, strontium-90, ruthenium-106, cesium-137, uranium, and plutonium.

The 216-A-10, 216-A-36B, and 216-A-37-1 cribs were monitored under a RCRA assessment program in 1999. The sites are monitored together under an assessment plan (PNNL-11523) because they have similar hydrogeology and waste constituents and appear to have contaminated groundwater. Combining these cribs into one RCRA groundwater monitoring area saves sampling and analysis costs because the number of near-field wells is reduced. Many of the far-field wells that formerly were sampled annually are now sampled every 3 years. These wells mainly track the extent and flow rate of the extensive iodine-129, nitrate, and tritium plumes that change very little in a 3-year period.

During 1999, iodine-129, gross beta, nitrate, and tritium continued to exceed interim drinking water standards or maximum contaminant levels in large areas downgradient of the Plutonium-Uranium Extraction Plant cribs. Strontium-90, a beta emitter, and gross beta exceed the interim drinking water

standards only in well 299-E17-14, which is near the 216-A-36B crib. Elevated manganese is found in wells 299-E25-19 and 299-E25-17 (both near the 216-A-37-1 crib). However, manganese exceeded the 50-mg/L maximum contaminant level only in well 299-E25-19.

**216-A-29 Ditch**. This is an inactive earthen ditch ~2 kilometers (1.2 mile) long in the 200-East Area that conveyed Plutonium-Uranium Extraction Plant chemical waste to the 216-B-3 pond from 1955 to 1986. The ditch received effluents that contained dangerous chemical and radioactive contaminants. Of primary concern for RCRA regulations were discharges of sodium hydroxide and sulfuric acid, which occurred daily as a result of ion-exchange regeneration at the Plutonium-Uranium Extraction Plant.

This RCRA unit continued to be monitored under an interim status indicator evaluation program in 1999 and did not have an adverse impact on groundwater. Indicator parameter data from upgradient wells were statistically evaluated, and values from downgradient wells were compared to values established from the upgradient wells. All replicate averages for contamination indicator parameters were below critical mean values or limits of quantitation during 1999.

The groundwater monitoring plan for the 216-A-29 ditch was revised in fiscal year 1999 (PNNL-13047). The current network is adequate for detection monitoring.

**216-B-3 Pond (B Pond)**. This former pond in the 200-East Area consisted of a main pond and three expansion ponds (216-B-3A, 216-B-3B, and 216-B-3C). The main pond began operating in 1945 and the expansions were built in the 1980s. In 1994, the main pond ceased operating, and the waste streams were rerouted to the 216-B-3C expansion pond and the 200 Areas Treated Effluent Disposal Facility. The main pond was filled with clean soil, and the expansion ponds were clean-closed (i.e., deemed free of dangerous waste and no longer regulated under RCRA). In August 1997, waste streams received by the expansion pond were diverted to the 200 Areas Treated Effluent Disposal Facility, thus ending operation of the B Pond system. In the past, B Pond received liquid waste from B Plant and the Plutonium-Uranium Extraction Plant, consisting of chemical sewer waste, cooling water, and steam condensate. These waste streams contained aluminum nitrate, nitric acid, potassium hydroxide, sulfuric acid, tritium, and other acids. In its later years, B Pond received nondangerous, nonradioactive effluent primarily from the Plutonium-Uranium Extraction Plant and B Plant.

In 1999, groundwater monitoring at B Pond continued under an interim status indicator evaluation program. The RCRA site was monitored under an assessment program from 1990 until January 1998 because of elevated total organic halides in two downgradient wells (699-43-41E and 699-43-41F). Assessment results (PNNL-11604) concluded that no hazardous waste constituents affected groundwater quality beneath B Pond despite erratic, low levels of total organic halides. The site was returned to an indicator evaluation program. Groundwater beneath the site apparently was affected by tritium and nitrate from past discharges to B Pond. However, all replicate averages for contamination indicator parameters were below critical mean values or limits of quantitation during 1999.

One new well was drilled in 1999 to improve the monitoring network. The network is designed to intercept potential contamination entrained in groundwater at some distance from the facility and contamination potentially entering groundwater from the vadose zone near the facility. With the addition of the new well, the network is adequate to detect potential contamination from the facility.

**216-B-63 Trench**. This 200-East Area trench received liquid effluent from the B Plant chemical sewer from March 1970 to February 1992. The liquid effluent consisted of a mixture of steam condensate and raw water. Past releases to the trench

also included sulfuric acid and sodium hydroxide solutions. Radioactive soil was dredged from the trench in August 1970, but no records exist of radioactive waste disposal to the trench.

In 1999, RCRA monitoring continued to indicate that no dangerous nonradioactive constituents from the site have entered groundwater. The well network was sampled twice for the indicator parameters pH, specific conductance, total organic carbon, and total organic halides. All replicate averages for contamination indicator parameters were below critical mean values or limits of quantitation during 1999.

**216-U-12 Crib**. This crib in the 200-West Area received wastewater containing dangerous chemical waste and radionuclides from April 1960 until February 1988. It continued to be monitored under an interim status assessment program in 1999. Assessment monitoring began in 1993 because of high specific conductance in two downgradient wells (WHC-SD-LEF-EV-001, Rev. 0). The crib will not receive additional effluent and is scheduled, according to provisions of the Hanford Site RCRA Permit (Ecology 1994), to be closed under RCRA final status regulations in 2005.

In 1999, network monitoring wells were sampled quarterly for constituents of interest. Based on the results of the assessment investigation (PNNL-11574), the site remains in interim status assessment monitoring because of continued elevated levels of nitrate and technetium-99. However, the objective of the assessment monitoring, rather than delineating the existing plumes, is to 1) determine whether the flux of constituents into the groundwater is increasing, staying the same, or decreasing; 2) monitor the known constituents until a near-term interim corrective action is defined; and 3) monitor until a final status plan is implemented. Nitrate, which had a source at this crib, remained elevated above the 45-mg/L standard in all downgradient wells in 1999. Nitrate and technetium-99 concentrations are decreasing in most of the wells.

Currently the 216-U-12 crib is monitored by only one upgradient well and two downgradient wells. Declining water levels have rendered other downgradient wells dry in the past year. The groundwater monitoring network is not adequate for RCRA interim status monitoring. The upgradient well, 299-W22-43, is now projected to go dry before the end of 2000. Two additional wells, one upgradient and one downgradient, are proposed for installation in 2000.

**216-S-10 Pond and Ditch**. The facility consisted of an open, unlined ditch and an open, unlined percolation pond in the 200-West Area. The pond and ditch received radioactive and dangerous chemical waste from the Reduction-Oxidation Plant from 1951 until 1985, when the pond and the lower part of the ditch were decommissioned and backfilled. The upper part of the ditch continued to receive nondangerous, unregulated wastewater from 1985 through 1991.

During 1999, this facility continued to be monitored semiannually under a RCRA interim status indicator evaluation program. Statistical evaluation of indicator parameter data from downgradient wells indicates that the site is not affecting groundwater quality.

Chromium remained elevated above the 100-mg/L standard in the upgradient well. The concentration peaked at 576 μg/L in 1997 and declined to 213 μg/L in 1999. Because the upgradient well is located adjacent to the 216-S-10 pond, it is unclear if the elevated chromium is from an upgradient source or from past discharges to the pond. To assess the chromium source further, a proposal is being drafted to reclassify this well as a downgradient well and replace it with a new upgradient well.

Currently the 216-S-10 pond and ditch are monitored by only one upgradient well and two shallow downgradient wells because other wells have gone dry. The groundwater monitoring network is not adequate for RCRA interim status monitoring.

One new downgradient well is being installed downgradient of the pond and will provide groundwater data for the continued evaluation of the elevated chromium. Two additional wells, one upgradient and one downgradient, are proposed for installation in 2000.

## 6.1.7.4 200 Areas Low-Level Burial Grounds

The low-level burial grounds are divided into five low-level waste management areas in the 200 Areas (see Figure 6.1.10). However, Low-Level Waste Management Area 5 has not been monitored for groundwater since 1996 because the burial ground never received waste. The remaining low-level waste management areas are in the indicator parameter phase of RCRA groundwater monitoring.

**Low-Level Waste Management Area 1**. This waste management area in the 200-East Area consists of the 218-E-10 burial ground. Disposal activities began in 1960 and continue today. Materials placed in this facility are primarily failed equipment and mixed industrial waste from the Plutonium-Uranium Extraction Plant, B Plant, and N Reactor.

Groundwater monitoring under interim status requirements continued at this RCRA site in 1999. Downgradient monitoring well 299-E33-34 continued to exceed the critical mean for specific conductance in samples from June 1999. This exceedance appears to be related to the nitrate plume and is not related to Low-Level Waste Management Area 1. A letter of notification was submitted to the Washington State Department of Ecology on March 18, 1999. Because no waste has been placed in the northern portion of this site and there is a nitrate plume from an upgradient source, no further action is necessary.

**Low-Level Waste Management Area 2**. This waste management area in the 200-East Area includes all of the 218-E-12B burial ground, which has been in use since 1968. The waste consists primarily of miscellaneous dry waste and submarine reactor compartments. Parts of two trenches contain transuranic waste.

This RCRA site continued in interim status indicator evaluation in 1999. Upgradient well 299-E34-7 exceeded the critical mean value for specific conductance, which was based on historical upgradient data. Specific conductance has been increasing in this well since 1997. The major contributors to the increase are sulfate and calcium. The source of these constituents is not known. However, there is only 0.6 meter (2 feet) of water remaining in this well, which is completed at the top of basalt, and the increase may be related to the basalt chemistry. An additional exceedance occurred in the quadruplicate average for total organic halides at well 299-E34-3 in January 1999. However, two of the four reported results are probably erroneous and have been flagged in the database. The quadruplicate average from April 1999 was well below the critical mean value.

**Low-Level Waste Management Area 3**. The 218-W-3A, 218-W-3AE, and 218-W-5 burial grounds in the 200-West Area make up this area. Burial ground 218-W-3A began accepting waste in 1970 and received primarily ion-exchange resins and failed equipment (e.g., tanks, pumps, ovens, agitators, heaters, hoods, vehicles, accessories). Burial ground 218-W-3AE began operating in 1981 and contains low-level and mixed waste, including rags, paper, rubber gloves, tools, and industrial waste. Burial ground 218-W-5 first received waste in 1986, and contains low-level and low-level-mixed waste, including lead bricks and shielding.

This RCRA site continued to be monitored under interim status indicator evaluation requirements in 1999. Indicator parameter data from upgradient wells were statistically evaluated, and values from downgradient wells were compared to values established from the upgradient wells. Critical mean values for the contamination indicator parameters were not exceeded in any of the wells monitoring this waste management area.

Several of the groundwater monitoring wells are approaching the point where representative sampling will no longer be possible because of the declining water table. Additional wells are planned in 2000.

**Low-Level Waste Management Area 4**. This area in the 200-West Area consists of the 218-W-4B and 218-W-4C burial grounds. Burial ground 218-W-4B first received waste in 1968 and contains mixed and retrievable transuranic waste in trenches and caissons. One caisson is believed to contain mixed waste. Waste was first deposited in burial ground 218-W-4C in 1978 and was classified as transuranic, mixed, or low-level and included contaminated soil, decommissioned equipment, and remote-handled transuranic waste.

Background concentrations for the general contamination indicator parameters were re-established in 1999 because the influence of a nearby pump-and-treat system is causing a reversal in the groundwater flow direction. The critical mean value for total organic halides was exceeded in one downgradient well in January and July 1999. This well used to be an upgradient well, and the exceedance is believed to be caused by carbon tetrachloride from an upgradient source.

Indicator parameters will not be evaluated statistically until groundwater flow stabilizes. Meanwhile, wells are sampled semiannually to determine when flow stabilizes and to maintain continuity in the database. This monitoring network is marginally adequate to detect releases from Low-Level Waste Management Area 4. Additional monitoring wells may be necessary in the future, as the water level continues to decline and to provide greater downgradient coverage. There are tentative plans to change the designation of this waste management area so that it will no longer be a RCRA facility. If this change occurs, additional monitoring wells will not be installed, and groundwater monitoring will defer to surveillance monitoring.

## 6.1.7.5 Liquid Effluent Retention Facility

This facility consists of three lined basins located east of the 200-East Area and serves as temporary storage for condensate from the 242-A evaporator. Constituents detected in the effluent stream from the 242-A evaporator were acetone, aluminum, ammonium, 1-butanol, 2-butanone, tritium, strontium-90, ruthenium-106, and cesium-137.

This facility is subject to final status monitoring and is included in the Hanford Site RCRA Permit (Ecology 1994). Until the final status plan is approved by the regulators, groundwater is monitored under the existing interim status plan (WHC-SD-EN-AP-024, Rev. 1). In 1999, groundwater monitoring indicated that no dangerous, nonradioactive constituents from the site have entered the groundwater.

Specific conductance in two downgradient wells exceeded the critical mean value in January 1999. DOE notified the Washington State Department of Ecology and submitted a groundwater quality assessment plan and report in March 1999. The plan concluded that the Liquid Effluent Retention Facility was not the source of the high specific conductance and detection monitoring should continue.

In June 1999, downgradient well 299-E26-9 was removed from the monitoring network because it went dry. In September 1999, the Washington State Department of Ecology directed DOE to continue the current monitoring using three wells (one upgradient and two downgradient) for 18 months. During this period, an alternative method of monitoring should be identified.

## 6.1.7.6 316-5 Area Process Trenches

These two unlined trenches in the 300 Area were used for the disposal of liquid wastes generated

in the 300 Area, beginning in 1975, and received uranium and other radioactive and chemical constituents. From 1985 through 1991, the trenches received nondangerous effluent, and all discharges ceased in 1991.

This site continued to be monitored with a final status corrective-action network in 1999. The objective of groundwater monitoring during the corrective-action period is to monitor the trend of the constituents of concern to confirm that they are naturally attenuating, as expected by the CERCLA record of decision for the 300-FF-5 Operable Unit (Record of Decision 1996). A proposed groundwater monitoring plan for corrective action calls for samples from the same wells as in the compliance period, but with fewer independent samples from each well during each sampling period (i.e., four to one). Also, each well showing an exceedance of one of the constituents of concern will be sampled quarterly to better follow the trends of contaminant concentration. The other wells in the network will continue to be sampled semiannually. The proposed plan is being reviewed by the regulator. Until the proposed plan is implemented, the final status compliance monitoring program (WHC-SD-EN-AP-185, Rev. 1) remains in effect. This plan calls for four independent groundwater samples from each network well (eight) during each semiannual sampling period.

In 1999, uranium, trichloroethylene, and cis-1,2-dichloroethylene continued to exceed concentration limits specified in the permit. Uranium, gross alpha, and tetrachloroethylene exceeded maximum contaminant levels in one or more wells monitoring near the water table. Cis-1,2-dichloroethylene and trichloroethylene exceeded standards in one downgradient well that monitors the base of the unconfined aquifer. Concentrations of uranium and various volatile organic compounds rose sharply in 1995 after the large quantities of relatively clean waste cooling water ceased to be discharged to the 316-5 process trenches. However, since that time, concentrations of those constituents have begun a slight downward trend as was expected.

### 6.1.7.7 Nonradioactive Dangerous Waste Landfill

The Nonradioactive Dangerous Waste Landfill (Central Landfill) in the 600 Area southeast of the 200-East Area received waste from 1975 through 1985 that included asbestos, miscellaneous laboratory waste, solvents, paints, sewage, acids, batteries, and mercury.

This site continued to be monitored under an interim status indicator evaluation program in 1999. Statistical evaluations indicated the site has not adversely affected groundwater quality. The groundwater monitoring plan for the landfill was rewritten during 1999 (PNNL-12227) to update the operating procedures and bring the plan up to date with the current monitoring well network and constituents monitored.